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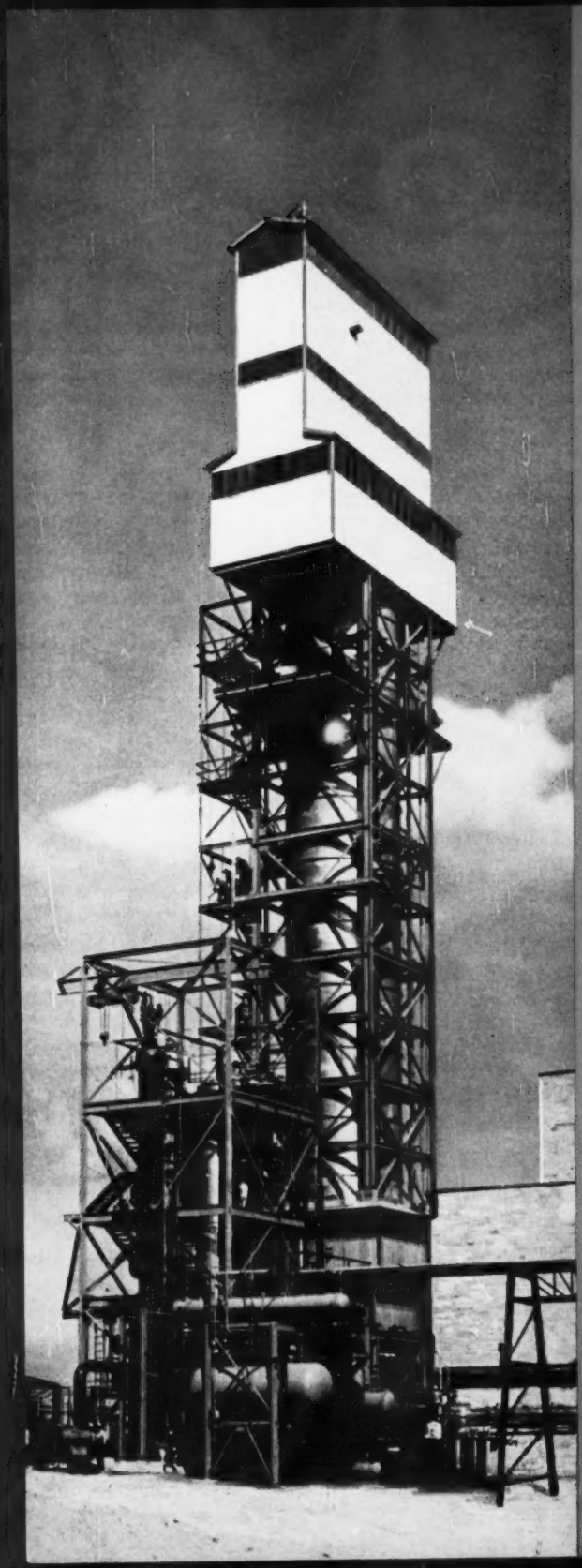

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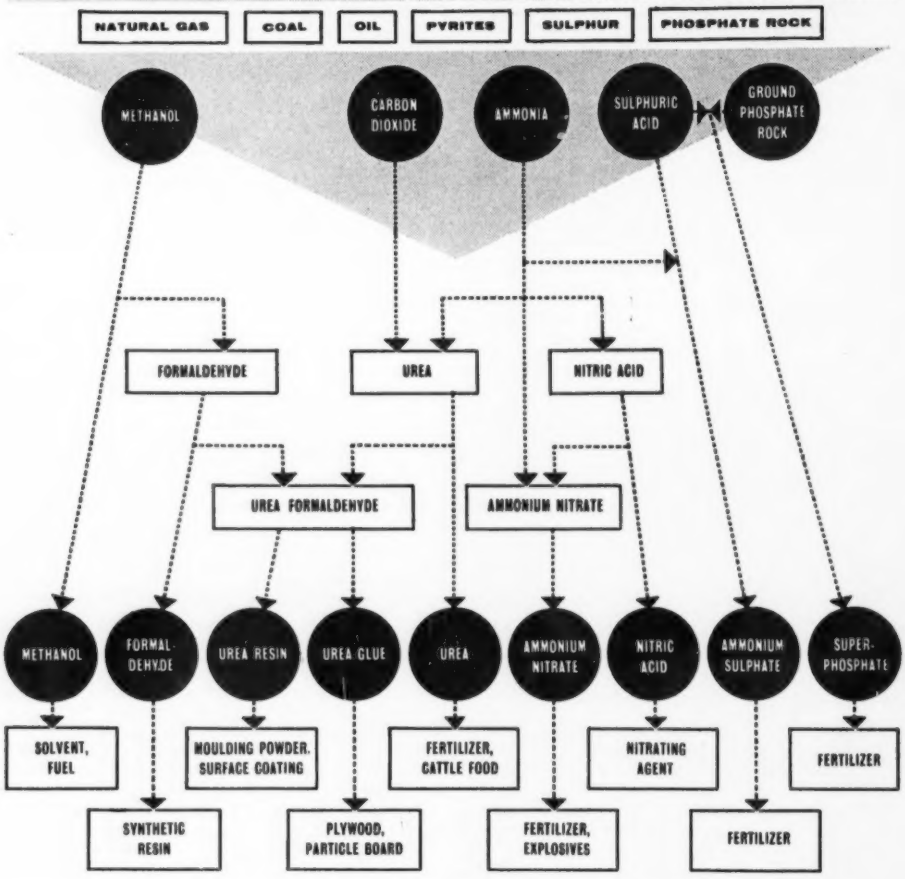

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"NITROGEN"

special announcement

WE are pleased to inform our subscribers that we have arranged with **Aikman (London) Limited** that in future their Annual and Half-Yearly Reports will be published exclusively in our magazine "**Nitrogen.**" The Annual Reports will appear in the November issues, commencing in November 1959, and the Half-Yearly Reports in the May issues commencing May 1960.

There will be no change in the presentation of these Reports which will continue to be written by Aikman (London) Limited and which will express their views and findings. We feel that the addition of these old established and important reviews, giving an independent Brokers assessment of the World Nitrogen market situation, will significantly add to the value of the contents of our magazine "Nitrogen." We are convinced that this combination of the resources of information of our two unique organisations will enhance the scope and coverage of nitrogen markets, statistics and kindred subjects presented in our magazine "Nitrogen" and so give the best service to the World Nitrogen Industry.

TECHNICAL CONSULTANCY SERVICE

We take this opportunity of drawing our readers attention to the fact that The British Sulphur Corporation Ltd. provides a Technical Consultancy Service, established over three years ago in support of our other publication "Sulphur." The service initially aimed at providing from a central focus a wide choice of expert and impartial advice on technical problems relating to the production and consumption of sulphur in all forms, including critical examination of new projects and process and advice on production methods. Within the last 12 months our standing panel of Consultants has been fortified by the addition of the services of :-

Messrs. L. H. Manderstam & Partners, Consulting Engineers,
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The panel is fully competent to deal comprehensively with the technical problems of the Nitrogen industry as well as those of the Sulphur industry. The service offered extends from dealing with specific queries on individual problems to the economic evaluation of new projects and processes and the planning of new plants.

All work undertaken by the Corporation is treated as confidential. Results and patent rights arising from experimental work are the exclusive property of the client.

UREA

IN AGRICULTURE AND INDUSTRY throughout the world the importance of urea is rapidly increasing and its production, which has trebled since 1954, is now at an annual level of 1½ million tons containing approximately 650,000 tons of nitrogen. Urea is produced as a white, crystalline solid, in prilled form or as a solution and, as manufactured, contains 46% N, although in the course of processing the nitrogen content may decline to 44%. As a fertilizer, applied in solid form or as a solution, urea is used on a wide range of crops and with particular success on wheat, rice, pasture, tobacco, cotton and citrus fruits. With a higher nitrogen content than any commercial fertilizer material with the exception of anhydrous ammonia, urea may be handled, stored and shipped with complete safety; moreover it is cheaper to produce per unit of nitrogen than ammonium nitrate. The economy effected by transporting material with a high nitrogen content is another factor in making urea a relatively cheap source of this plant nutrient.

The use of urea as a feed for cattle and sheep to make up the deficiency of low protein carbohydrate feeds is extensively developed in the United States, although elsewhere it has not yet made its mark. Consumption of urea for this purpose, amounting to 75,000 tons a year, now accounts for 6% of the total world usage.

Whilst the agricultural consumption of urea in 1958 is approximately 2½ times that in 1954, the industrial usage has, in the same period, increased nearly five-fold. In addition to some 245,000 tons of urea used annually in the manufacture of synthetic resins, many other industrial applications are assuming a growing importance, particularly in the manufacture of detergents and cosmetics and in the treatment of textiles, woodwork and metals, which raise technical urea consumption to over 400,000 tons a year.

An important feature of the post-war activities in this sector of the nitrogen industry has been the development of a number of commercial urea manufacturing processes to which the growth of urea production on a broader basis may be primarily attributed.

MANUFACTURE

In preparing urea by the isomerization of ammonium cyanate in 1828, Wöhler is generally believed to have achieved the first synthesis of an organic material from an inorganic source. Until then it was widely held that the compounds occurring in animals and plants had some kind of "vital source" which distinguished them from inorganic compounds and Wöhler's discovery helped to break down the sharp boundary between organic and inorganic chemistry. Since that time several methods have been developed for the synthesis of urea, that of primary importance being the dehydration of ammonium carbamate, as this method forms the basis for all commercial processes. This reaction can be illustrated by the following equation :—

$$2NH_3 \text{ (Ammonia)} + CO_2 \text{ (Carbon Dioxide)} \rightleftharpoons NH_4COONH_2 \text{ (Ammonium Carbamate)} \rightleftharpoons NH_2CONH_2 \text{ (Urea)} + \text{Water}$$

The advantage of this reaction, which only attained commercial importance in 1920 when the I.G. Farbenindustrie used it as the basis of a commercial process, is the use of relatively cheap raw materials, carbon dioxide being obtained as a by-product of the hydrogen produced for ammonia synthesis. All commercial processes for urea manufacture follow the same basic sequence.

Ammonia and carbon dioxide are fed under pressure into a reactor which is maintained at a sufficiently high temperature and pressure to form a melt of ammonia, ammonium carbamate, carbon dioxide, urea and water. The specific temperature at which the melt must be maintained in the reactor is between 135°C and 210°C according to the process used, the pressure being between 1,500 and 5,000 lbs. per square inch. The main variables which affect this reaction—temperature, pressure, feed composition and reaction time—are all interrelated and all affect the yield of urea, the heat balance and the corrosion of the materials of construction. On leaving

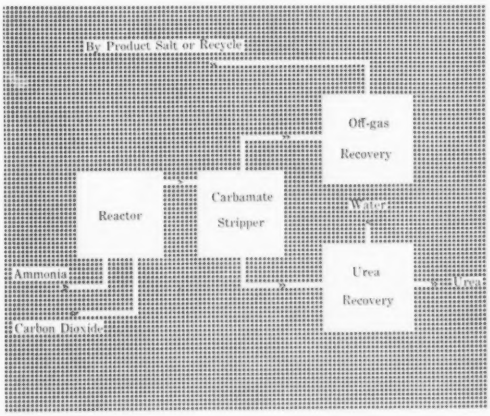


Fig. 1. Simplified flowsheet of the Urea process.

the reactor, the melt flows in a continuous stream through a pressure reduction valve to the carbamate stripper where it is separated into a liquid phase of urea and water (in some instances with varying amounts of ammonium carbamate and ammonia) and a gaseous phase of ammonia, carbon dioxide and small quantities of water vapour. The urea in liquid phase is used in the preparation of solutions or it can be further processed to produce solid urea prills or crystals. The gaseous phase can either be recycled or used in the production of salts.

Biuret

If temperatures much above 110°C are used in the carbamate stripper, some of the urea will decompose to biuret, a compound harmful to germinating seeds and animal life and which must also be kept to a minimum in urea intended for the manufacture of urea-formaldehyde resins. The higher the temperature, the faster the decomposition will be. The interrelation of temperature and biuret formation is particularly important at the prilling stage.

The U.S. Department of Agriculture has recommended that the biuret content should be kept below 2%, but some crops, pineapples for example, cannot stand a biuret content of more than 1%. In plant design it has therefore become mandatory to produce urea with a biuret content below this level to cover the widest possible market.

Corrosion

The most important problem associated with the manufacture of urea is corrosion which principally affects the reactor, the pressure reduction valve and the equipment handling hot ammonium carbamate solution.

The conditions in the reactor most conducive to a high urea yield, namely high pressure and temperature and a minimum of excess ammonia, are also the conditions which accelerate corrosion. The effect of corrosion in urea manufacture is so serious that the reaction must be conducted under conditions which afford a tolerable corrosion rate rather than those which result in maximum yield of urea.

There is a considerable amount of data available—much of it conflicting—on the wide range of materials which have been tested under urea manufacture operating conditions which are so severe that even glass has a corrosion rate of 0.6 inches a year. Tantalum appears to have the best resistance to corrosion but its use in commercial plants is at present prohibited by its cost, and various types of stainless steel are the materials most widely used.

Off-Gas Recovery

The rate of conversion of carbon dioxide to urea for each cycle of the process is only about 50% and usually even less since an excess of ammonia is normally used. To improve the economies of the process, the gaseous phase of the product of the carbamate stripper is either recycled to the reactor or recovered for the manufacture of other nitrogen salts.

The reactor stage and the processing of the urea solution are basically alike in the commercial processes now in use and their principal differences lie in the methods of off-gas recovery and processing, and the effect of this operation on the rest of the process.

Once-Through Process

The off-gases, on leaving the carbamate stripper, are not recycled to the reactor, but for this process to be economically attractive, the unconverted ammonia and carbon dioxide and in particular the ammonia must be recovered in some way. In most cases this is done by neutralization with sulphuric, nitric or phosphoric acid to form a by-product ammonium salt for sale (Fig. 2). At the Toulouse installation of the Office National Industriel de l'Azote, ammonia and carbon dioxide are reacted with calcium sulphate giving ammonium sulphate and calcium carbonate. A Japanese patent proposes the use of the ammonia and carbon dioxide off-gases for production of ammonium bicarbonate.

The principal advantage of this process is the relatively low capital outlay whereas the major drawbacks are a high rate of corrosion and the need for an economic source of sulphuric, nitric or phosphoric acid supply. Every one of the urea processes in commercial use can be operated as once through systems. A notable example of a process which is essentially a once-through system, although it provides for recovery of some of the ammonia at various points of the gas flow, is the Stamicarbon process. Its modest capital cost, high efficiency and other design features which fit it readily into the plant layout of installations producing a variety of nitrogenous fertilizers, has made it attractive to an increasing number of fertilizer manufacturers.

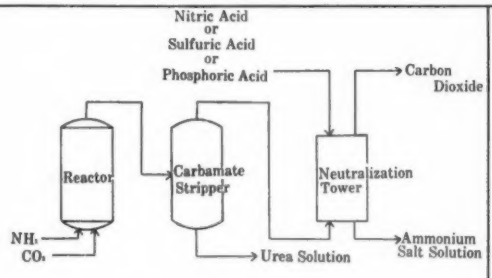


Fig. 2 Once Through Process

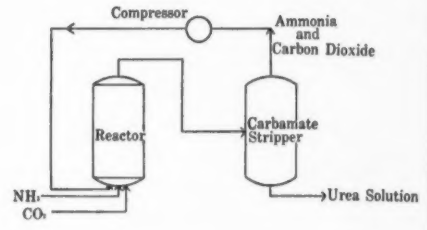


Fig. 3 Hot Gas Recycle System

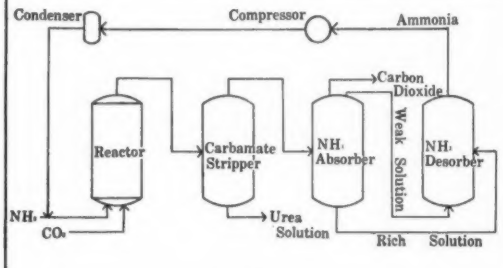


Fig. 4 Inventa Process

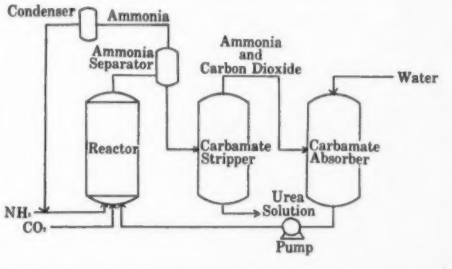


Fig. 5 DuPont Solution Recycle Process

"Hot Gas Recycle" Process

In this process (Fig. 3) the unconverted ammonia and carbon dioxide are raised to the synthesis pressure and recycled to the reactor. This affords good overall conversion of the ammonia and carbon dioxide but very close temperature control must be maintained during this recompression stage of the off-gas to prevent the formation of solid ammonium carbamate with consequent damage to the compressors. In the reactor, the temperature control of the highly exothermic reaction is made more difficult by the entry of the compressed hot off-gas stream.

This process was first introduced at the works of Badische Anilin und Soda Fabrik at Oppau in West Germany but the high capital cost, considerable operating difficulties and severe corrosion of the plant militated against the extension of its use.

"Inventa" Process

On leaving the carbamate stripper the unconverted gases are fed into an ammonia absorber where the ammonia is absorbed in an aqueous urea nitrate solution and insoluble carbon dioxide is vented. The "ammonia rich" stream flows to an ammonia desorber and beyond this the ammonia gas is compressed to reaction pressure and then liquified in a condenser before being fed into the reactor.

This process affords good overall ammonia conversion with relatively low operating costs. The liquid ammonia recycle assists in the control of the reactor temperature, thereby reducing corrosion.

"Du Pont" Solution Recycle Process

The unconverted ammonia and carbon dioxide from the carbamate stripper are absorbed in water to form an ammonium carbamate solution which is pumped back to the reactor (Fig. 5). Since an excess of water in the reactor would tend to decrease the urea yield, a large quantity of excess ammonia is extracted from the melt in an ammonia separator located between the reactor and the carbamate stripper. The separated ammonia is condensed and recycled to the reactor.

The advantages of this process are that it affords good overall conversion of both ammonia and carbon dioxide and that the excess water used in the carbamate solution assists in the temperature control of the reactor. It has, however, the disadvantage that the excess water makes it necessary to employ very high temperatures (200-210°C) and pressures (400 atm.) in the reactor in order to obtain a good conversion at each cycle. Conditions in the reactor are highly corrosive, even silver lining being attacked at these high temperatures. Moreover, for the process to be economically successful a large capacity plant is required.

"Chemico" Process

In that only the unconverted ammonia is recovered, this is similar to the "Inventa" process. Recovery is accomplished by feeding the unconverted ammonia and carbon dioxide gases from the carbamate stripper into a carbon dioxide absorber (Fig. 6). The carbon dioxide is absorbed selectively in a monoethanolamine solution and the unabsorbed ammonia passes through and is compressed, condensed and then recycled to the reactor. The "carbon dioxide-rich" monoethanolamine solution is then regenaretd in a desorber, the carbon dioxide being driven off and vented.

The principal economic advantage of the Chemico process as compared with others is that only a relatively small volume of gas has to be re-processed in the absorption-separation plant.

Fauser-Montecatini Recycle Process †

Quite apart from the Fauser-Montecatini once-through process there are three alternative arrangements whereby ammonia and carbon dioxide are recycled. In partial recycle, off-gases are liquified and the carbamate solution recycled. Of the two total recycle processes, one is based on the selective separation of the gaseous phase and the other on the total recycle of the liquified off-gases.

In the selective recycle process, first 75% of the unreacted ammonia and carbon dioxide are recycled as an aqueous solution of ammonium carbamate mixed with fresh ammonia in a two-section expander condenser, the solution entering the reactor at 160-180°C and 160-180° atm.g. In a second circuit the remaining 25% of the unreacted ammonia and carbon dioxide are recycled after separation from the urea solution to an absorber where

† For further details see Nitrogen No. 1, February 1959.

the ammonia is selectively absorbed by an aqueous solution of urea nitrate. The solution is regenerated, the desorbed ammonia returned to the cycle and the unabsorbed carbon dioxide is vented.

This process has the advantage of high carbon dioxide conversion (approximately

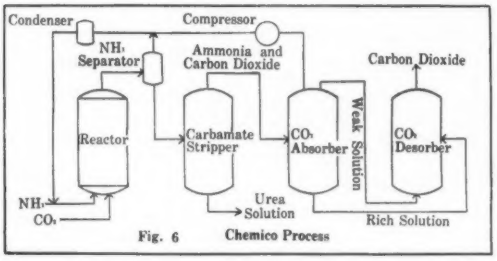
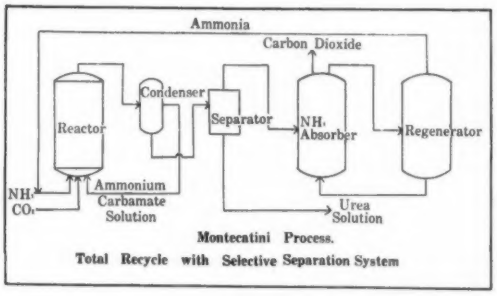


Fig. 6 Chemico Process



Montecatini Process.
Total Recycle with Selective Separation System

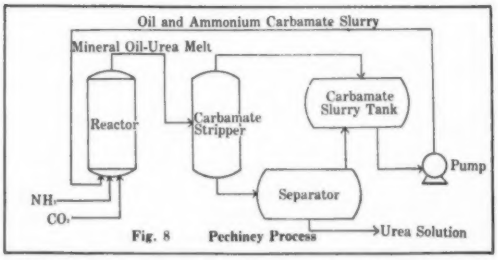


Fig. 8 Pechiney Process

70%) low operating costs and reduced compressor requirements since the bulk of the distillation gases are returned to the cycle as an ammonium carbamate solution. The use of relatively low pressures and temperatures reduce the corrosion rate and the reactor can be made of stainless steel, no silver lining or other expensive material being required.

Total recycle in liquid phase is the latest arrangement of the Montecatini process and the off-gases, after being separated under low pressure from the urea solution after the first recycle are condensed and returned to the reactor in a second circuit.

This arrangement is claimed to afford reduced operating costs and although slightly less efficient than the selective recycle system, is much simpler to operate as several items of equipment are eliminated.

Pechiney Process

The outstanding feature of this process is the use of a mineral oil as the medium in which ammonium carbamate is recycled. The mineral oil-urea melt passes from the reactor to the carbamate stripper where unconverted ammonia and carbon dioxide are driven off (Fig. 8). The liquid phase from the stripper is decanted in an oil separator. Urea solution is withdrawn from the bottom while the layer of oil is transferred to a carbamate slurry tank where the unconverted gases from the carbamate stripper react to form crystals of ammonium carbamate. The slurry of oil and ammonium carbamate is then recycled to the reactor.

The Pechiney process, whilst entailing a relatively high capital outlay, affords good overall conversion of both ammonia and carbon dioxide and the presence of oil assists in controlling the reactor temperature and also reduces the corrosion problem.

PRODUCTION

Although production of urea on a commercial basis has been carried on since the 1920's, and although the potentialities of urea have long been apparent, it is only since 1950 that there has been any significant increase in its production and use. The delay in the growth of urea production has been largely caused by plant operating problems, particularly that of corrosion, and the resulting high cost of the end product. Many of these problems remain unsolved but improvement in plant design and operating technique has done much to enhance the economic advantages of urea manufacture.

A major factor which has contributed towards the expansion of urea production has been the development of its technical applications in number and importance during the last ten years. The growing use of urea as an animal feed in the United States and its use

as a solution in fertilizer formulations have also stimulated the growth of production capacity.

This capacity, which has increased eight-fold since 1950, is still concentrated in Western Europe, the United States and Japan where the expansion has taken place at a greater rate than in the rest of the world.

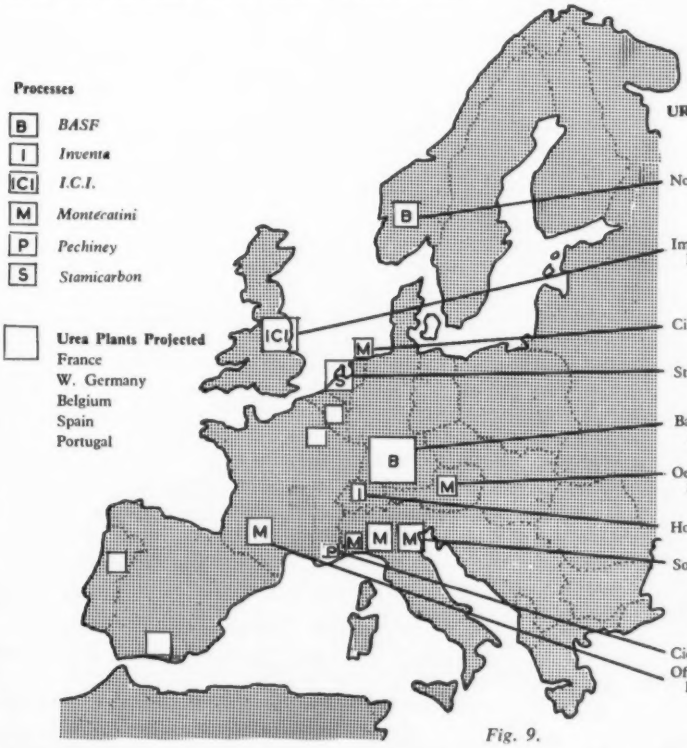
	World Urea Capacity (tons urea per annum)	
	1.1.1950	*1.1.1959*
Western Europe	50,000	421,500
U.S.A.	150,000	750,800
Japan	20,000	719,000
Other	10,000	42,500
	230,000	1,931,800

In the same period world production of urea has increased from about 190,000 tons to 1.45 million tons urea. The highest rate of increase has occurred within the last four years when production expanded 3½ times whereas between 1950 and 1954 it rose by only 125%.

Western Europe

Urea manufacture was first carried out on a commercial basis in Germany nearly 40 years ago, but it is only within the last three years that there has been any marked increase in production capacity. During this period, capacity has risen by 112,000 tons a year, an increase of nearly 60% and now amounts to 420,000 tons a year. Currently over 90% of urea capacity appears to be employed and in 1958 is estimated at 390,000 tons.

Within Western Europe the bulk of urea production originates in Western Germany, the United Kingdom, Belgium, Holland and Italy, although growing interest in this material is being shown by nitrogen producers in France and Spain.



UREA PLANTS IN OPERATION January, 1959

Company	*Location*	*Capacity (tons p.a.)*
Norsk Hydro	Eidanger	33,000
Imperial Chemical Industries	Billingham	70,000
Cie Néerlandaise de l'Azote	Sluiskil ...	15,000
Statsmiinen im Limbourg	Geleen ...	50,000
Badische Anilin & Soda Fabrik	Oppau ...	132,000
Oesterreichische Stickstoffwerke A.G. ...	Linz ...	14,000
Holzverzuckerungs A.G. ...	Erns ...	3,500
Soc. Montecatini	Novara ...	30,000
"	Ferrara ...	30,000
"	San Guiseppi di Cairo	7,000
Cie Pechiney	St. Auban	2,000
Office National Industriel de l'Azote	Toulouse	35,000
Total		421,500

Fig. 9.

In addition to the capacity now in operation some 70,000 tons are now under construction and will come on stream before 1961. A 50,000 ton per year plant using the Stamicarbon process is being built at Tertre in Belgium for Carbochimique S.A. and another of 20,000 tons capacity is under construction for the Ste. Finalens at La Bassée. Both these

plants are due for completion this year, while others are projected plants in Western Germany, France, Spain and Portugal. At this rate of expansion, installed plant capacity is likely to rise by about 60% to total nearly 700,000 tons by 1963.

mont, Delaware. A further 96,000 tons will be added to North American urea capacity with the completion of the second of two new plants in Canada. A 66,000 ton per year plant employing the Chemico process has been completed in recent weeks for Cyanamid of Canada

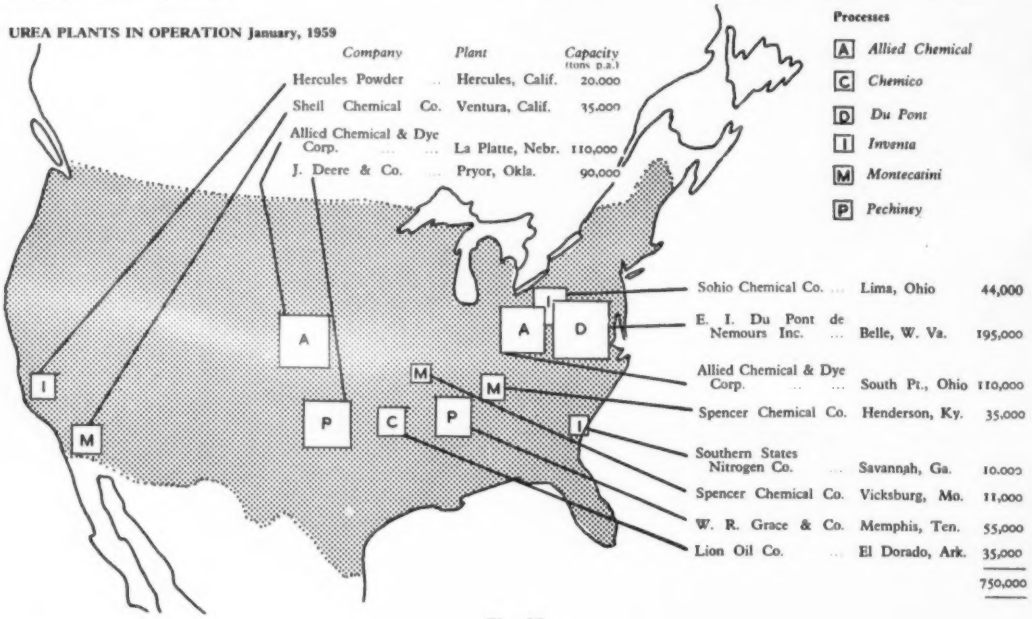

UREA PLANTS IN OPERATION January, 1959
Company
Plant
Capacity (tons p.a.)
Hercules Powder ... Hercules, Calif. 20,000
Shell Chemical Co. Ventura, Calif. 35,000
Allied Chemical & Dye Corp. ... ... La Platte, Nebr. 110,000
J. Deere & Co. ... Pryor, Okla. 90,000
Processes
A Allied Chemical
C Chemico
D Du Pont
I Inventa
M Montecatini
P Pechiney
Sohio Chemical Co. ... Lima, Ohio 44,000
E. I. Du Pont de Nemours Inc. ... Belle, W. Va. 195,000
Allied Chemical & Dye Corp. ... ... South Pt., Ohio 110,000
Spencer Chemical Co. Henderson, Ky. 35,000
Southern States Nitrogen Co. ... Savannah, Ga. 10,000
Spencer Chemical Co. Vicksburg, Mo. 11,000
W. R. Grace & Co. Memphis, Ten. 55,000
Lion Oil Co. ... El Dorado, Ark. 35,000
750,000

Fig. 10.

North America

Production capacity in North America, which at the end of 1958 was still confined to the U.S.A., has increased sharply since 1954 and now exceeds 750,000 tons annually, representing over 38% of the world total. It is estimated that about 70% of capacity is employed and production in 1958 totalled about 520,000 short tons.

Three plants under construction are due for completion in 1959 and will raise urea capacity to 878,000 tons a year. The Co-operative Farm Chemicals are building a 10,000 ton per year plant using the Chemico once through process at Lawrence, Kansas; W. R. Grace & Co. are doubling the present capacity of their Pechiney type plant at Memphis, Tennessee; and the Sunolin Chemical Co. are installing a 73,000 ton per year plant using the Montecatini process at North Clay-

at Hamilton, Ont. A plant with a capacity of 30,000 tons per annum is projected for Cominco at Turner Side, Calgary.

Plans are well advanced for the erection at Yazoo City by the Mississippi Chemical Corp. of a 35,000 ton per year plant using the Inventa once through process. In addition several nitrogen fertilizer manufacturers are giving consideration to urea projects and although plant construction activity in North America is now at a somewhat lower level than it was a year ago, it can be assumed that urea production capacity will reach 1.25 million tons a year by 1963.

Japan

The most remarkable expansion in urea capacity has taken place in Japan where it has increased 16 times since 1950 and now amounts to 719,000 tons, representing 37% of the world total; although Japan's plant capacity is

surpassed by that of the United States her output of urea in 1958 was the largest in the world, amounting to 552,000 tons.

Japanese capacity will be raised by 33,000 tons a year when extensions to the Nihon Gas Chemical Industries plant at Niigata are completed by Chemical Construction Corporation. No further projects for the immediate future have been reported, but as Japan's nitrogen industry is being rationalised, further urea plant capacity can be expected; possibly at the expense of other nitrogen fertilizer facilities, and by 1963 installed capacity is likely to exceed 1 million tons.

Japanese Urea Capacity on 1.1.59

Company	*Plant*	*Process*	*Capacity (tons p.a.)*
Toyo Koatsu Industries Inc.	Hokkaido	Toyo Koatsu	95,000
Toyo Koatsu Industries Inc.	Ohmta	Toyo Koatsu	75,000
Toyo Koatsu Industries Inc.	Niigata	Toyo Koatsu	44,000
Nihon Gas Chemical Industries	Niigata	Chemico	29,000
Kiowa Hakko Kogyo	Ube	Montecatini	25,000
Mitsubishi Chemical Industries	Kurosaki	Montecatini	58,000
Nippon Suisu	Matzusima		8,000
Nisan Chemical Industries	Toyama	Montecatini	44,000
The Nito Co.	Yokahama		17,000
Peipu Co.	Upeh		37,000
Sanyo Co.	Upeh		50,000
Showa Denko	Kawasaki		53,000
Sumitomo Chemical Industry Co.	Niihama	Chemico	65,000
Toyo Gas	Niigata		44,000
Ube Industries	Ube	Montecatini	65,000
			719,000

Other Countries

In 1950 there were no urea plants outside Europe, North American and Japan and capacity in Communist countries was then represented by the small (10,000 tons per annum) plant at Leuna in East Germany. By 1960, 379,000 tons of capacity will have been installed in the rest of the free world, and a further 518,000 tons will be added by 1962.

This substantial rate of urea capacity increase accords with the present trend of nitrogen plants being erected in the areas of consumption.

In addition to plants under construction, several more are under consideration, including one in Brazil and one in Indonesia ; it can be expected that during the next 10 years urea capacity in Africa, Asia and South America will increase at a faster rate than in Europe, North America and Japan. It is estimated that in the U.S.S.R. current urea capacity is about 30,000 tons a year, but the trend of expansion of the chemical industry and in particular of fertilizer production is such that a substantial increase in urea capacity in the U.S.S.R., Eastern Europe, and possibly even in China, must be foreseen. It is likely that by 1963 urea plant of 250,000 tons per annum capacity will be installed.

Urea Capacity—Other Countries

Country	*Company*	*Plant*	*Process*	*Completion*	*Capacity (tons p.a.)*
South Africa	African Explosives & Chemical Industries Ltd.	Modderfontein	Stamicarbon	1959	110,000
India	Neyveli Lignite Corp.	Neyveli	Undecided	1960	152,000
	Sindri Fertilizers	Sindri	Montecatini	1961	24,000
E. Pakistan	Pakistan Industrial Development Corp.	Fenchuganj	Chemico	1961	106,000
W. Pakistan	Pakistan Industrial Development Corp.	Multan	Inventa (total recycle)	1961	59,000
Formosa	Taiwan Fertilizer Co.	Nankong	Inventa (total recycle)	1959	160,000
South Korea	Government	Chungju	Inventa	1959	85,000
South Korea	Government	Nanju	Undecided	1961	85,000
British West Indies	Federation Chemicals Ltd.	Trinidad	Stamicarbon	1959	35,000
Bahamas	Caribbean Chemical & Fertilizers	Freeport	Undecided	1961	54,000

APPLICATIONS AND CONSUMPTION

Fertilizer

The rapidly growing acceptance of urea as a fertilizer is due not only to its high nitrogen content, which affords economies in packing, transport and cost of application, but also to its intrinsic properties in that it has good leach resistance in the soil, it leaves no soil residues and is easy to handle. Moreover, it does not corrode application equipment.

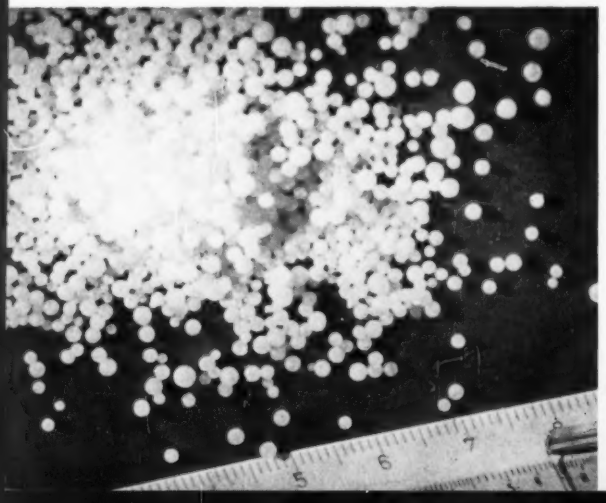
Because urea technically bears comparison with other types of nitrogen fertilizers this critical assessment of it under specified conditions of use is particularly important. Much research into the effects of urea as a fertilizer is still being carried out, but its salient qualities are already widely recognised.

Plants are able to absorb urea directly, although this process is slower than with nitrate nitrogen and ammonia nitrogen. Urea as such is quite short lived in the soil, as it is biochemically converted into ammonium bicarbonate. Under favourable conditions this transformation is very rapid and the resulting ammoniacal nitrogen may in time be directly absorbed by the plant roots or, for the most part be changed into nitrate nitrogen. The factors governing this transformation are soil moisture, temperature, nature of the soil and the availability of other basic fertility elements, mainly assimilable phosphorus and potassium.

Rice and Leaching

Urea nitrogen is comparatively resistant to leaching; it appears to hydrolise in soil liquids with the soil bacteria and enzymes accelerating its conversion to ammonium bicarbonate which is quickly converted by soil acids to a form resistant to leaching. Thus, despite the great solubility of urea it is tenaciously held by the soil. This has the effect of reducing the soil acidity and binding the ammonia nitrogen, affording obvious advantages on irrigated land.

Urea pills produced by the Stamicarbon process.



In tests conducted by the U.S. Department of Agriculture on the effect of applying ammonium sulphate, ammonium nitrate and urea to rice crops, urea was found to yield some 10% more rice per pound of nitrogen than ammonium sulphate and nearly 50% more than ammonium nitrate.

From a strictly agronomic point of view, urea nitrogen may be regarded as similar to ammonia nitrogen and although nitrate nitrogen is generally considered to be the more effective on plants with a deep root system and crops with a cycle confined to the cold season, for the great majority of crops, urea nitrogen has practically the same value as either nitrate or ammonia nitrogen.

Briefly then, the conclusions which may be drawn from the results of research into the use of urea as a fertilizer are as follows :—

1. Urea, as such or compounded, constitutes an excellent source of nitrogen for all plants.
2. It can be used either as a solid or dissolved in combined operations of fertilization and irrigation.
3. Its behaviour in the soil and the nature of its nitrogen content place urea in an intermediate position between the ammonia/cyanamide type fertilizer and the nitrate materials, so that, depending on local conditions, it can perform the function of either of these types.
4. Urea is particularly suitable for application on citrus fruits, pineapple, banana, coffee, sugarcane, cotton, maize, wheat, potato, tomato, pasture, tobacco, rice.

Urea Solutions

The use of urea in solution as a fertilizer is becoming increasingly important, particularly in the United States, where half the total fertilizer urea consumption is in this form. Urea solutions may be applied as such or compounded with ammonium nitrate, ammonia and other nitrogen materials.

Some widely used compound solutions are :—

	% of Weight				
Free ammonia ...	24.5	26.0	28.0	36.8	30.6
Ammonium nitrate	56.0	50.0	40.0		
Urea	10.0	12.0	15.0	32.5	43.1
Water	9.5	12.0	17.0	30.7	26.3
Total	100.0	100.0	100.0	100.0	100.0
Nitrogen content ...	44.40	44.46	44.03	45.43	45.28

For use on vegetables, flowers and young fruit trees, urea may be applied as a solution with ammonia, but the urea used should contain less than 0.25% biuret.

Analysis of a " Foliar " Grade Solution

Nitrogen	46%	Minimum
Biuret	0.05%	
Moisture	0.1%	Maximum
Ash	33 ppm	Maximum
Iron	2.0 ppm	
Free ammonia	5.0 ppm	
PH (10% solution)	6.9	
Colour (APHA)	5.0	
Turbidity (ppm as SiO_2) ...	10.0	

Urea-Form

A recent development of rapidly growing importance in the United States is the use of urea-form—urea formaldehyde—with a molar ratio of urea to formaldehyde greater than one. Although a comparatively expensive product, urea-form affords a slower and more controlled rate of nitrogen release than is possible with conventional fertilizer. It can be used in complex formulations and in mixtures during ammoniation and granulation. At present the principal application for urea-form fertilizers is on turf grass. Some 200,000 tons of nitrogen were used on turf grass in the United States in 1958, but it is estimated that a potential market of over four times this quantity exists, and it can be expected that the demand for urea-form will grow steeply within the next 10 years.

Animal Feed

Urea may be used to supply up to one-third of the protein requirements of ruminant animals such as cattle and sheep and permits the use of cheaper, low protein, carbohydrate feeds. The urea provides the nitrogen needed for the biochemical synthesis of proteins by the micro-organisms in the " second stomach " of ruminants. It also assists in digestion of cellulose in the animals' diet. Animals with a single stomach do not have the necessary enzymes for using it but the bacteria in the rumen of cattle, sheep and goats transform urea to ammonia and carbon dioxide. If too much urea is administered in the feed, the transformation is incomplete and part of the ammonium carbonate formed is converted to toxic ammonium carbamate which, depending on the excess present, can cause sickness or death to the animal and for this reason strict precautions must be taken. This threat is avoided by ensuring that the feed is properly balanced and in particular that the carbohydrate content is high enough to keep the bacteria which assimilate urea in condition. In some cases nearly three-quarters of the animal's nitrogen supply can be given in the form of urea without harmful effects, provided that a rich feed is given.

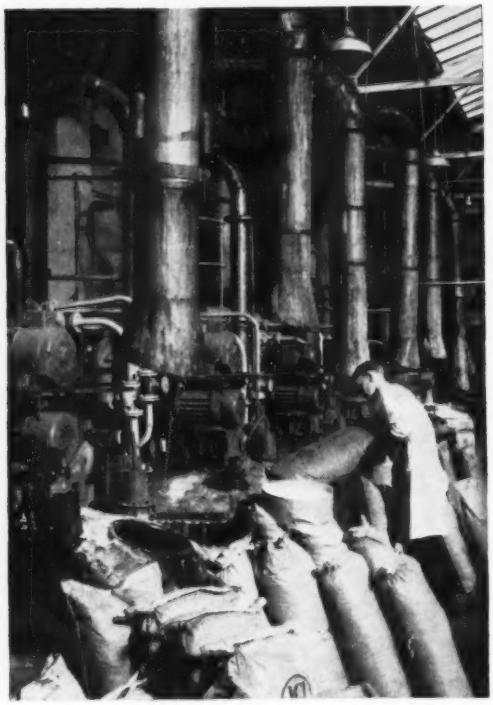
The carbohydrates which have given the best results with urea are alfalfa and soya, whereas feeds based on molasses are less satisfactory. It has been found that methiomine increases the beneficial effects of urea. Urea may also be associated with the use of silage, although numerous tests have shown that in this case the addition of carbohydrate is also essential.

Although there are numerous variations in feeds containing urea according to the carbohydrates available and the type of farming, three main types can be distinguished; for growth in young animals, for fattening adult animals, and for dairy cattle. It is important to note that the use of urea appears to have no effect on the quality of the meat or milk produced. The various types of ruminants respond in much the same way to the addition of urea in their feeds and it is probably true that it enables them to absorb more salt. On the other hand, the effect on poultry and pigs has been negative.

In addition to natural feeds, urea is facing competition from several other chemical products, and in particular propionamide, which gives good results and has the advantage of being completely non-toxic. It is, however, considerably more expensive. Ammonium bicarbonate is also more expensive, is more volatile and is more dangerous to use as it is more easily transformed to ammonium carbamate. Diammonium phosphate appears to have some advantages over urea, but tends to be difficult to handle because it must be extremely pure and contain no trace of chlorine. Ammoniated beet pulp with 2 or 3% nitrogen is another alternative but its use is unlikely to become very widespread.

Urea Based Resins

The largest industrial use of urea is in the production of thermosetting resins and of these by far the most important is urea-formaldehyde. These resins are nearly colourless and may be pigmented to almost any colour. Consumption of urea in their manufacture rose from 60,000 tons in 1954 to 350,000 in 1958.



British Industrial Plastics. Urea being charged into a reaction vessel containing formalin in the manufacture of urea-formaldehyde resins.

The principal applications for resins containing urea are in the treatment and coating of high grade paper, as adhesives and binders, particularly for plywood, for treating and dressing textiles, as protective coatings and as moulding powders.

Plastics with a urea-formaldehyde base are usually sold as specialised lines in which price and quality are both important factors and which are widely used in screw stoppers for perfume and cosmetic bottles, for electrical fittings and in the manufacture of radio and television cabinets. For hidden internal fittings, however, the cheaper phenolit plastics are preferred as they are just as effective from an electrical standpoint, have better dimensional stability and are less sensitive to temperature and water.

Further applications for urea-formaldehyde resins are being studied and in particular their use in the crease-proof treatment of textiles. In this sphere they may well play an important part in the competition between natural and synthetic fibres. Another outlet for urea is in the urea-melamine resins which in specific fields compete with urea-formaldehyde.

Other Applications

The expanding consumption of urea in other industrial applications is in part governed by the physical properties of the product as well as by its function in promoting chemical processes or reactions. It is used as an ingredient in softeners for many products based on cellulose such as glassine and other papers, cellophane, cellulose sponge and wood. The addition of urea to casein, animal glue, gelatine and starch sizes and adhesives for paper products results in a reduction of viscosity and permits the use of higher concentrations of active material. The Petroleum Industry is finding an important application for urea in the separation of straight chain hydrocarbons from other types by extractive crystallization, although this use has not yet been widely developed.

Applications for urea in the Chemical Industry include the preparation of barbituric acid, caffein, ethylurea, hydrazine, melamine, guandine, urea perioxide and sulfainic acid. Sulfainic acid and its salts are used as softening agents for textiles and paper, as flame retardents, weed killers, metal cleaners and electroplating salts.

The medicinal and miscellaneous applications of urea are numerous. Urea is used medicinally as a diuretic, a synergist for certain sulfa drugs and in veterinary medicine with sulphur to control coccociosis in poultry. Cosmetic applications include use in some deodorants, skin creams and lotions.

Finally, urea is used in the manufacture of dyes and pigments, synthetic detergents, beer, explosives and as a blowing agent for porous rubber.

Consumption

World consumption of urea in 1958 is estimated to have totalled 1.3 million tons. The growth of urea use, particularly marked within the last five years when world consumption has trebled, has been most prominent in fertilizers. These now account for about 815,000 tons of urea a year, an increase of about 570,000 tons, representing about 5% of the total world consumption of fertilizer nitrogen. Within the same period consumption of urea for synthetic resins has risen by 135% to an annual level of 245,000 tons, while its use in animal feeds amounting to 38,000 tons in 1954, now amounts to about 75,000 tons a year, but is as yet virtually confined to the United States.

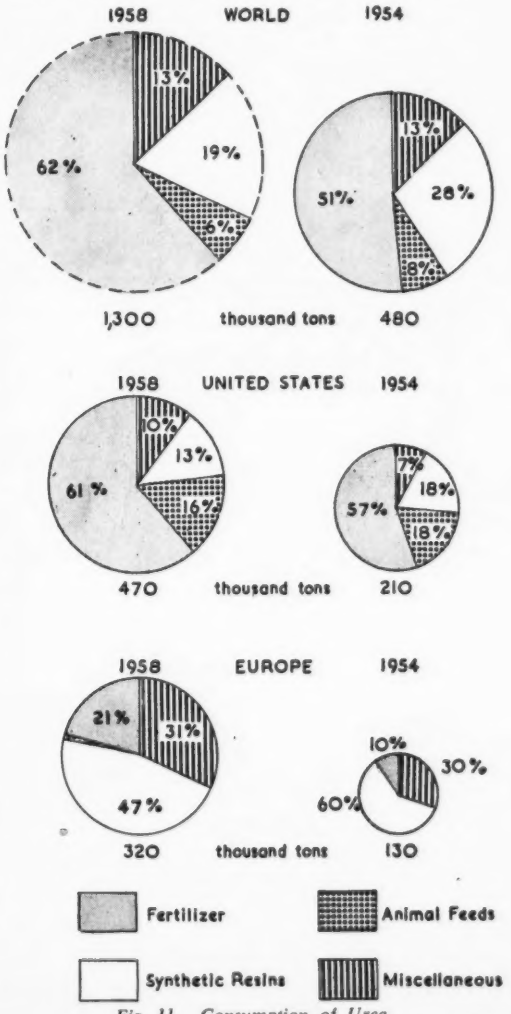


Fig. 11. Consumption of Urea.

North America

In North America the widespread acceptance of urea as a fertilizer and the steady, if less spectacular, growth of industrial demand have raised urea consumption to an annual level of 546,000 short tons*, an increase of 310,000 tons in five years. Of this total, the rapidly expanding usage in Mexico accounts for about 50,000 tons, virtually all as fertilizer, whereas in Canada demand is as yet negligible. Agricultural usage for fertilizer and animal feeds in North America is now at a level of 432,000 short tons, having expanded 2¼ times since 1954. The growth of fertilizer urea consumption has been stimulated by the widespread development of its use in solutions and complex formulations which account for approximately one-half of the total.

The industrial consumption of urea in North America, at present virtually confined to the United States, has doubled within the last five years and amounts to about 110,000 tons annually, of which synthetic resins account for over one-half.

Western Europe

In Western Europe, industrial application, which in 1954 accounted for 70% of total urea consumption, has risen at a faster rate than agricultural usage and is now at an annual level of 250,000 tons of which about 60% is devoted to the manufacture of synthetic resins. Technical urea consumption is most prominent in Western Germany, where it is at an annual level of about 110,000 tons and in the United Kingdom, where it amounts to about 70,000 tons.

In Western Europe, urea has not so far achieved popularity as a fertilizer commensurate with that it enjoys in the rest of the world, due to a large extent to a more conservative outlook of both consumers and producers. In competition with the range of nitrogen fertilizers now in use, urea has had to meet principally the price factor in respect of ammonium sulphate and the well-established popularity of ammonium nitrate. Nevertheless, urea is gaining ground as a fertilizer in Western Europe and consumption has risen over 1½

* Excluding Hawaii.

times since 1954. Its use in animal feeds is still largely in the experimental stage and this as yet does not constitute an important market.

Asia and Australasia

Almost entirely in the form of fertilizer material, consumption of urea in Asia has risen speedily since 1954 and now represents a third of the world total. This development has been most marked in Japan, India and South Korea, where fertilizer consumption has risen by 130, 140 and 250% in the last five years.

UREA CONSUMED AS FERTILIZER (tons urea)

	1954/55	*1957/58*
Japan	110,000	254,000
India	27,000	64,000
South Korea	8,000	28,000
Australia	300	7,000

This rise in urea fertilizer consumption can partly be attributed to its suitability for rice cultivation. At the same time, Asian fertilizer supplies are heavily subsidised by foreign aid and consequently any price differential between urea and other nitrogen fertilizers there may be tends to be softened.

Industrial consumption of urea is largely concentrated in Japan where it is now at an annual level of 30,000 tons, of which the bulk is used in the manufacture of synthetic resins.

Eastern Europe and China

Very little is known of the breakdown of urea consumption in Eastern Europe, the Soviet Union and China, but considerable interest is being shown in its potentialities in industrial as well as agricultural use. Applications already developed on a substantial scale include its use in the manufacture of urea formaldehyde resins, particularly in East Germany and the U.S.S.R.

Africa

Now at an annual level of over 40,000 tons, urea consumption in Africa has doubled in four years, largely due to the very substantial quantities used in the cotton crop in the Sudan. The Union of South Africa, and Federation of Rhodesia and Nyasaland are other sectors where the use of fertilizer urea is developing.

Central and South America

Stimulated by the existence of the substantial capacity and urea output in North America which seeks an export market, and by its effectiveness on citrus fruits, pineapple, banana, coffee, sugar cane and tobacco, urea is rapidly establishing a foothold in Central and South American agriculture. Growth of consumption is particularly noticeable in Honduras, Guatemala, Columbia and Brazil. This trend is at present very marked in Central America, where consumption of 30,000 tons a year has trebled since 1955. Outstanding consuming countries are Honduras and Guatemala, whereas in South America urea use has developed more slowly and is still largely confined to Brazil and Columbia.

Summary and Outlook

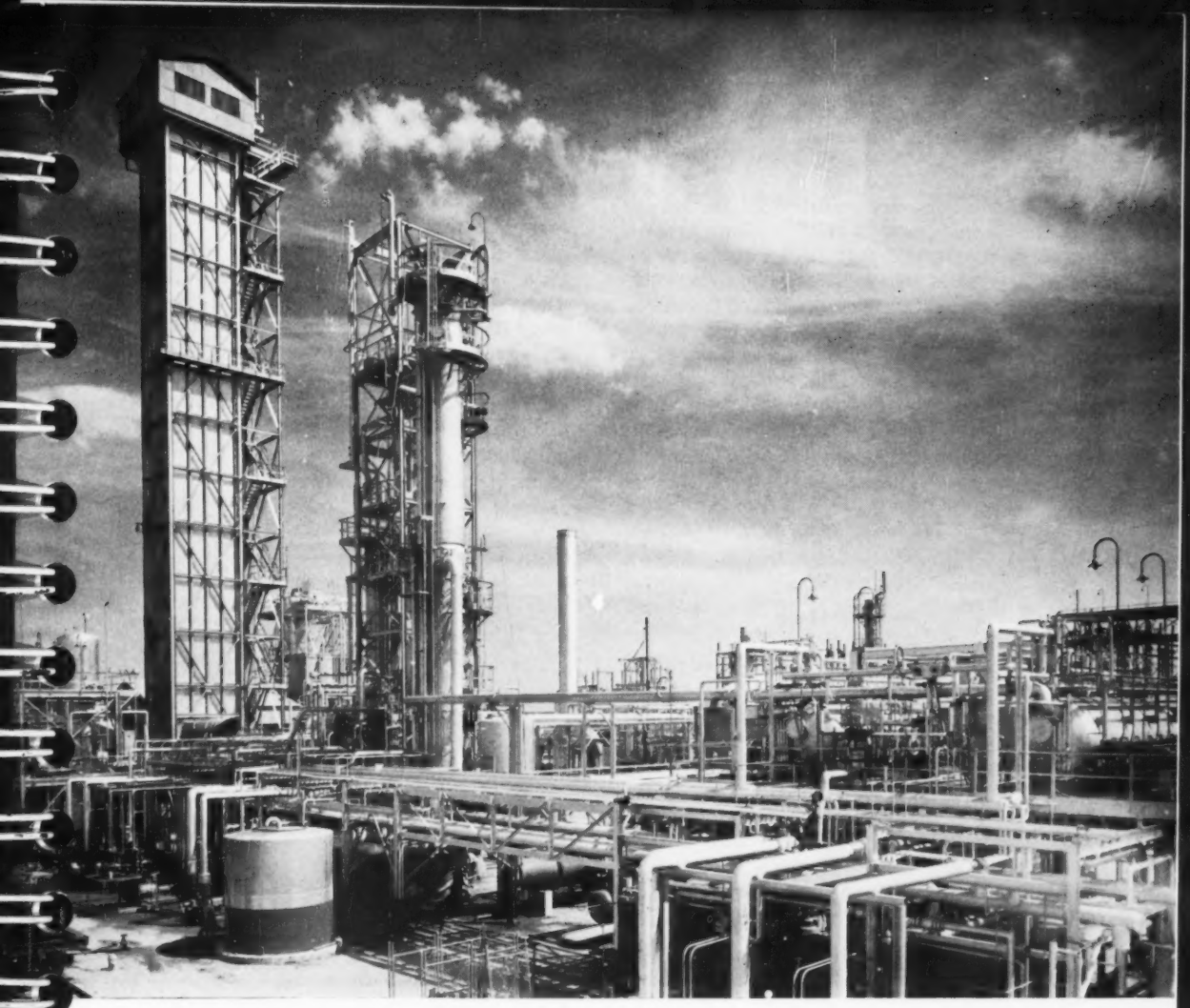
To-day urea accounts for approximately 6% of world nitrogen production and consumption, the highest level of activity in major countries being attained in Japan, where urea represents approximately one-fifth of the total nitrogen consumption. In the last five years world consumption of urea has grown by 820,000 tons and, as indicated in the table below, its growth factor has been by far the largest of all nitrogenous materials.

EXPANSION OF CONSUMPTION 1954-1958

	Urea	Thousand Tons "N"	Total	Ammonium Sulphate	Ammonium Nitrate
World	+171%	820	+46%	+31%	+70%
West Europe	+146%	190	+35%	+29%	+39%
U.S.A.	+110%	230	+35%	+39%	+58%
Asia	+390%	380	+56%	+67%	+50%

Whereas in the early stages of commercial urea use the emphasis was on its technical applications, the spectacular growth since 1953/54, and probably also its future expansion, is linked with its use as a fertilizer. The above statistical analysis shows that Asia accounts for the largest quantitative increase and whilst this emphasises the salient fertilizer qualities which make urea eminently suitable for use on Asian crops, notably rice, and under Asian climatic conditions, it does not detract from its prospects in other parts of the world, notably in Western Europe and the United States, where the standards of fertilizer usage are already high and diversified.

Of some 410,000 tons of technical urea used currently throughout the world, about 250,000 tons are consumed in Western Europe. Here its use as a fertilizer has not yet been stimulated and technical users, notably the highly developed plastics industries of Western Germany, United Kingdom and France are mainly responsible for the apparent high rate of expansion of urea consumption. Thus it is seen that the ratio of consumption of urea by



J. Deere and Co. The Pechiney Urea plant installed at Pryor, Oklahoma, has an annual capacity of 90,000 tons.

industry and agriculture (including animal feed) is 7 : 2 in Europe, whereas the U.S. position is 2 : 7 and about 1 : 8 in the rest of the world.

A measure of the present-day popularity of urea is the comparatively high level of employment of productive capacity throughout the world and the impressive programme of new construction. As yet, no one manufacturing process appears to have shown a decisive advantage. All plant makers are faced with the problems of overcoming corrosion in reactor and ancillary equipment, of keeping the biuret content of the urea solution and prills as low as possible, and last but not least, of building plant with design features and at a capital cost conducive to progressive reductions of the cost of urea manufacture. At present there appears to be a distinct advantage with once-through plant which, being built at a relatively low capital cost, is dove-tailed into other nitrogen fertilizer activities. This method of urea production commends itself particularly where the outlet for urea is limited, and a substantial demand for other nitrogen products persists. The great strides in improving the technique of total recycle processes coupled with the economic advantages of large-scale operations point to the good prospects for this type of plant as local and world-wide urea consump-

tion attains a level commensurate with other nitrogen fertilizers.

Whereas to-day world production is at an annual rate of 1.45 million tons of urea, it is estimated that this will treble in the next four years and will reach 4.5 million tons by 1963. This anticipated increase of 1.4 million tons N in urea represents an average annual rate of expansion of 3% of total world nitrogen use and it is expected that this will represent about 50% of total growth. This rate would be substantially increased if the economics of manufacture were to show significant advantages over other forms of nitrogen production and thereby provide a more profitable conversion of ammonia. Already in Japan much obsolete ammonium sulphate plant is to be replaced by urea installations. In the United States the high nitrogen content of urea, its suitability as a raw material for both industry and agriculture as well as its versatility as a fertilizer have not yet been fully reflected in terms of plant expansion but may well provide the key for the better utilization of the growing surplus of ammonia capacity. The potentialities of the Central and South American fertilizer markets appear to be an added stimulus to the rapid expansion of U.S. urea capacity and supplies.

Similar considerations will unquestionably exert a growing influence on European nitrogen manufacturers, who have traditionally played a major part in world export markets. At ruling levels the comparable ex-works price, whether in Europe or in the United States, still shows urea to be more expensive per unit N content. In certain markets, however, especially in Asia where the freight cost plays a disproportionate role, urea has already been sold at unit prices showing a slight advantage over other N fertilizers. The merits of urea in the Asian agronomy are already evident. In Africa it could cause a large and almost untapped market to develop spectacularly. So far Western Europe's nitrogen industry has not made a place for urea in its pattern of fertilizer supply, possibly because its existing production facilities and domestic markets have not made such a development sufficiently urgent. As Western Europe leads the world in fertilizer consumption and production, the establishment of urea within the existing pattern would advance its already significant impact on the world nitrogen supply picture.

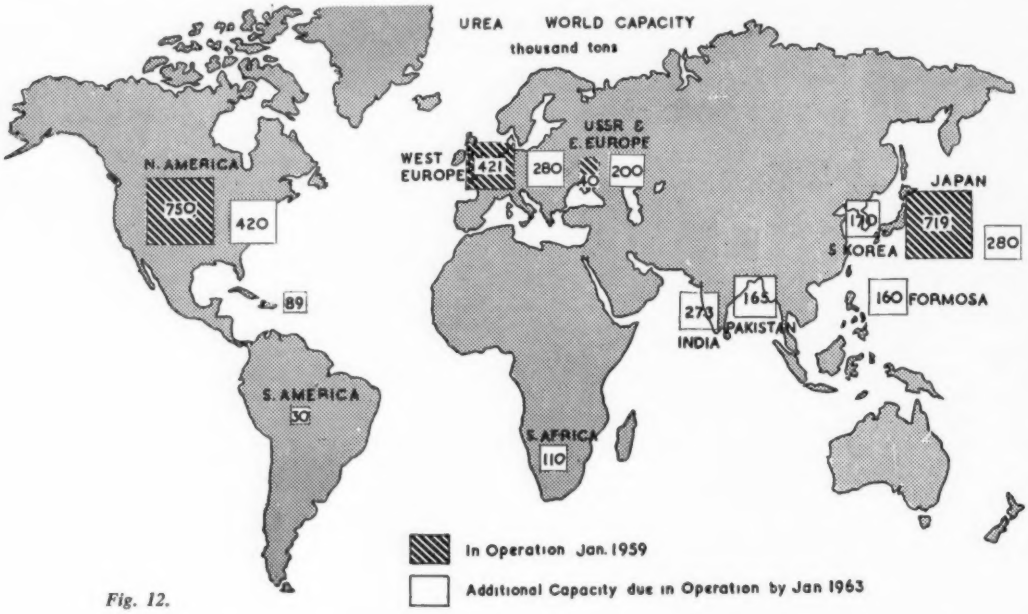


Fig. 12.

Supply · Trade · Prices

WORLD SUPPLIES of nitrogen readily entered markets in recent months as the main fertilizer season in the Northern Hemisphere which accounts for the bulk of world nitrogen consumption got under way. The consistent accumulation of stocks of all types of nitrogenous fertilizers notably of low-grade ammonium nitrate and urea, which had been particularly pronounced at the beginning of this year, was in part arrested and as deliveries accelerated in a number of markets minor supply shortages for spot deliveries have become evident. This general improvement of the tone of the market is attributable mainly to the influence of domestic demand in the major producing countries. Probably the largest single force in world trade—China's demand of nitrogenous fertilizers—has not yet exerted a clear impact and whilst there have been serious enquiries and some purchases, they appear to be still short of the level attained in 1957/58 when China imported about 270,000 tons N. Whereas the present position in world fertilizer markets is firm, the outlook for the fertilizer year 1959/60 is weak. A contributory factor is the progressive increase of new capacity notably in countries which hitherto have been major buyers of nitrogen from western Europe and North America. World synthetic ammonia capacity (excluding U.S.S.R.) has increased in the course of the current fertilizer year by about 650,000 tons N, representing about 7½% of installed capacity. It is further estimated that employment of installed capacity in Western Europe, North America and Japan has declined from about 81% to 77%. The level of world nitrogen consumption continues to advance faster than that of other fertilizers. World consumption of nitrogen and phosphoric acid (P_2O_5) (outside the U.S.S.R. and other Communist countries) now appears to be at a content ratio of 1 : 1 with Potash (K_2O) at a corresponding level of 0.85.

In the **United States** the level of nitrogen production has accelerated in common with the improved tenor of industrial activity. Output of synthetic anhydrous ammonia in 1958 rose 2½% to 3,831,000 short tons, but because of the relatively low employment of installed capacity—about 78%—the rate of new construction of ammonia capacity has declined. About 178,000 tons came into production in 1958 and 263,000 tons is scheduled for 1959. Preliminary data indicate that in the current fertilizer year domestic use of N fertilizer will be approximately 7% greater than in the preceding year and total about 2.65 million short tons N including 300,000 tons imported material. The use of nitrogen in liquid form notably ammonia, continues to advance and now represents about 55% of United States consumption.

Technical nitrogen uses continue expanding especially consumption of urea and of ammonium nitrate, the latter mostly in the form of solid fertilizer grade material for explosives. Nitric acid for technical and fertilizer uses is being produced at an annual rate of nearly 2.9 million tons (100% HNO_3) similar to the peak level attained in 1957. Strong by-product ammonium sulphate output which owing to intensive steel operations has risen within 10% of the high levels reached in 1957, boosted production in this sector to an annual rate of over 1.8 million short tons. Rapid disposals to home consumers notably mixers and to a lesser degree to export further reduced stocks from the modest level of 235,000 short tons prevailing at the end of February. Ammonium nitrate production has been checked and it is arising at an annual rate of 2.6-2.7 million short tons 100% solution; nitrogen solutions including combinations with urea were being produced in the early months of this year at an annual rate of close on 700,000 short tons N. Better weather has accelerated deliveries against contracts and boosted mixing operations with the result that prevailing strong demand and movement of current output and of stocks to users has given the market a firm tone. There are even spot shortages of ammonium sulphate, urea and

even anhydrous ammonia, but these are partly caused by transport difficulties.

The nitrogenous fertilizer output of **Canada's** Western provinces, represented by the activities of Consolidated Mining and Smelting Company and N.W. Nitro Chemicals Company augmented by the by-product ammonium sulphate supplies of Sherritt Gordon Limited nickel operations, continues to claim an important share of the market in the N.W. U.S.A. and competes effectively in Far Eastern export markets. The availability of low cost natural gas and oil as a source of hydrogen and energy points to the mounting importance of this source of nitrogen supply, on which an increasing number of new installations can be expected to be based. Due on stream this year is Cominco's 36,000 tons per annum N urea project. A similar expansion by Canada, where the advent natural gas supplies coupled with the transport advantages of the St. Lawrence seaway inaugurate a new set of conditions for the economic supply of nitrogenous fertilizers, raises Canada's production capacity to about 360,000 tons N. This gives her an export surplus in excess of one-quarter million tons N, effectively the third largest in the world.

In the **United Kingdom** the start—officially on May 22nd—of the Shell Chemical Company's 85,000-ton N ammonia plant at Shellhaven oil refinery is the first instance in this country of an entire N plant being based on a source other than coal gas. Imperial Chemical Industries Limited are at the same time contemplating conversion of their entire ammonia capacity to fuel oil as a source of hydrogen. The most recent addition to primary N production at the company's Billingham Division employs the Texaco process and it was in this, the new 60,000 tons ammonia plant, that in April an explosion damaged a compressor and so caused a deferment in the start of operations.

Producers on the Continent of **Europe,** notably those dependent on export markets for an outlet for the greater part of their output continued to curtail the rate of operation, but even so were forced to stockpile in excess of customary levels. In Italy, as the result of expansion by Soc. Montecatini and the new production by A.N.I.C., plant operations were reduced to 60% of installed capacity. In Western Germany, Belgium and France producers restraint was much in evidence; progressive improvement of facilities and the addition of several new plants augmented installed capacity by some 170,000 tons N. In Holland the high value of natural gas as a domestic and industrial fuel precludes its economic use as a source of hydrogen and fuel oil is becoming the main competitor of the coal gas supplies. The start of the fertilizer season has made some impact on the high level of nitrogenous fertilizer stocks, but so far the level of exports has not come up to expectations and in particular for the late summer and early autumn all exporters remain strong sellers. Nitrate stocks in particular but also urea stocks are heavy. Outstanding results in 1958 were achieved by Austria's nitrogen industry who represented by Osterreichische Stickstoffwerke A.G. of Linz exported 77% of the total N fertilizer output of 990,000 tons.

In **Japan** the industry's rationalisation efforts received added impetus by proposed legislation to finance the industry's projects from a special fund at 6½% instead of the customary 9% interest rate; to exempt the industry from paying import duty on fuel oil—at present 6½%—thus benefiting primarily the new installations and finally to reduce the industry's tax liability on income derived from ammonium sulphate exports from 5% to 3%. Except for the last named concession the Ministry of Finance is reported to have agreed with these proposals, resulting in an estimated saving of at least 400 million Yen (£400,000) annually. Funds made available for the rationalisation and expansion of industry amount to 4 billion Yen (£4 million) for the current year and 3 billion Yen each for 1960 and 1961 respectively. Currently heavy stocks of ammonium sulphate and urea are reported and these are estimated to total 120,000 tons N.

The volume of imports to meet requirements in the major markets of the **Far East** is progressively building up. Several bids for purchases by I.C.A. for South Korea are being awarded at the end of May and early June and whilst it has been suggested that urea should be excluded from imported supply to shield the

output of the new Chungju plant the final decision by the Combined Economic Board is still pending. To date funds for the purchase of about 40,000 tons N appear to have been allocated, about four-fifths for Government procurement and the balance through commercial channels.

South Vietnam is reported to be seeking 80,000 tons urea for 1959 rice crop. Purchases by Communist China in Western Europe are getting under way and to date Belgian and West German supplies to the extent of about 54,000 tons N and 60,000 tons N mostly as ammonium sulphate are reported to have been concluded. It is expected amongst European suppliers that the present rate of purchases may accelerate during the coming weeks, to reach the expected level of 250,000 tons N for 1959.

FREIGHT

Following the short lived firmness in freight markets as the result of greater demand for grain shipments, freight rates in April and May have once more weakened. Apart from isolated shortages of vessels which caused some local spot fixtures to be firmer, most rates for commodity shipments other than ore charters are slightly lower. An indication of current rates for vessels of 10,000-12,000 tons is as follows:—

To	*Japan*	*From U.S.A.*	*W. Europe (equivalent)*
China	—	—	51s.
India (W. Coast)	$6.50	—	48s. 6d.
Do.	35s.		
Central America	—	$13	30s. 6d.
East Africa ...	—	—	40s.
South Korea ...	$2.75-$3	$9	51s.
Greece	—	42s. 8d.	25s.

PRICES

The world price structure of nitrogen remains unstable although temporarily the decisive seasonal movement of fertilizers has caused some firmness of prices in the United States and a steadier tone in Western Europe. The state of over-supply, looking beyond the immediate campaign, is such that the entry of new capacity generally has now no longer an appreciable effect on the price structure. Especially the surplus in evidence in Europe and in Japan, is however, expected to cause severe price fluctuations where local markets or even contracts become the subject of intensive competition. The most recent practice of Japanese suppliers of quoting in markets not traditionally within the orbit of her industries, such as Greece, Africa, the Caribbean and the Pacific and Atlantic Seaboard of South America is particularly unsettling.

DOMESTIC PRICES

There has been no fundamental change in the principle or the level of price subsidy in the domestic markets of the major consumers, of whom the United States is an exception having a price structure which is competitive with that evident in world export markets.

United States

Although prices are firm the general price level is in common with world prices considered unfavourable. Ruling prices are as follows:—

Coke-oven ammonium sulphate
$32 per short ton f.o.b. in bulk
Synthetic ammonium sulphate
$35 per short ton f.o.b. in bulk
Ammonium nitrate (33.5% N)
$57 per short ton f.o.b. in bulk
Ammonium nitrate
$68 per short ton f.o.b. in bags
Calcium cyanamide
$57 per short ton f.o.b. in bags
Nitrogen solutions (40.8% N) basic 100%
$120 per short ton f.o.b. in tanks

Imported lime ammonium nitrate at port of discharge competes with domestic material at $45.50 per short ton in bags in rail cars at Hopewell Va., an advance of $1 since January 17th. Anhydrous ammonia (fertilizer grade) is quoted East of the Rocky Mountains at $88 per short ton in tanks, with refrigeration grade $2.50 dearer. In California the market remains in a state of flux as the major producers affirm their ability to compete in the range of $63-65 per short ton.

United Kingdom

Current quotations of United Kingdom nitrogenous fertilizers, delivered to the farmers' nearest railway stations are:—

	per ton	*subsidy*
Ammonium Sulphate (20.6% N)	£21 8 0	£9 18 0
Nitro Chalk (15.5% N)	£18 10 0	£7 7 6
Nitra-Shell (20.5% N)	£24 8 6	£9 14 9
Chilean Nitrate of Soda (16% N)	£27 5 0	£7 12 0

Nitra-Shell with 23% content quoted at £26 15s. (subsidy £10 18s. 6d.) and Magnesium Nitra-Shell at £27 8s. 6d. (subsidy £9 14s. 9d.) continue to attract custom. Demand for compounds, however, now that the season is

nearing its end has fallen off. A modest reduction is reported in the bulk price of ammonium sulphate. A substantial volume of ammonium sulphate has been imported in past months from the Continent, mostly Belgium, the price of which, after payment of duty (£4 per ton), compared favourably with the domestic price. The fertilizer subsidy under current price review is 9s. 6d. per long ton unit of Nitrogen.

Ammonium Sulphate

Current quotations in export markets range from about $33 per tonne f.o.b. in bulk. For material in bags posted prices in Western Europe are about $38-39 per tonne f.o.b. Amongst tender awards made in recent weeks a 158,000 tonnes for Spain indicated prices ranging from $33.07 to $39.77 per tonne. United States material in the lower price bracket secured about one-half of the tonnage, other supplies originating from West Germany, Poland and East Germany. Credit facilities of up to 18 months were extended. The awards of contracts for 100,000 tons ammonium sulphate by the Agricultural Bank of Greece encompassed Dutch (C.S.V.), Belgian (CoBelaz), Austrian (O.S.W.), West German (B.A.S.F., Höchst, Ruhrstickstoff) and Italian (S.E.I.F.A.) material at $42.40 per tonne c & f., and 50,000 tonnes secured by A.N.I.C. at $42.90.

The unit price of ammonium sulphate nitrate (26%N) in recent quotations appears to have become more competitive in relation to that of ammonium sulphate and lime ammonium nitrate. The contract awards by the Greek Agricultural Bank included 30,000 tonnes of ammonium sulphate nitrate which were secured by Ruhrstickstoff A.G. and B.A.S.F. at $51.50 per tonne c & f. The awards of tenders in Spain included 100,000 tons at $49.92 per tonne secured by Ruhrstickstoff A.G. and Cobelaz.

Ammonium Nitrate

Excessive supplies particularly in Western Europe have disproportionately weakened this market. Recent quotations were in the range of $60-62 per tonne f.o.b. in bags. Successful bids to the Greek Agricultural Bank covering 50,000 tons granular material ranged from $£64.75 per tonne c & f for U.S. material (33.9%-34.5% in bags) to $69.50 for Polish and Russian supplies.

Lime ammonium nitrate (20.5%) of West European origin is at present fractionally cheaper per unit of N than ammonium sulphate and successful bids to Spain were at $38.16 and $38.409 per tonne, but slightly lower quotations are also reported from other markets.

Urea

The present excess of supplies, notably of material of Japanese origin has unsettled this market. Offers ranging from $84 per tonne f.o.b. are reported. United States fertilizer grade urea prices have declined to about $95 whilst the bulk of quotations by other suppliers including West German, Dutch, Norwegian and Italian is in the bracket of $85-$92.

Other Nitrogenous Fertilizers

Sodium Nitrate: In the United States the domestic as well as imported Chilean material is quoted at $41.50 per short ton in bulk or $45.50 in bags. Material of German origin (16%N) was sold to Greece at $38.50 per tonne c & f.

Calcium Nitrate: Supplies by Norsk Hydro—10,000 tons—sold to Greece at $38.30 per tonne c & f.

Summary

The overall level of nitrogen consumption appears to be about 6% higher in 1959 than in the preceding year, but in view of the greater expansion of production facilities the gap between real supply and capacity on the one hand and demand and expected growth of usage on the other has further widened. This aspect of the supply picture appears to be already discounted in the general price levels obtaining at present and by restraint in the employment of productive capacity. During the summer months the seasonal rise in the general level of stocks will, under prevailing conditions of supply, inevitably cause a measure of unease. The tenor of markets despite the evident statistical weakness need not be upset although aggressive selling by individual producers—especially if conducted outside traditional markets—or any alarm caused by this or by the accumulation of disproportionate stocks in relation to available export outlets could set off a new decline of prices in the autumn.

Fisons Limited produce

AMMONIUM NITRATE

at Stanford-le-Hope

WITH a daily capacity of 400 tons of ammonium nitrate, a new factory built for Messrs. Fisons Ltd. at Stanford-le-Hope on the Thames Estuary was brought into operation in March. The decision to produce ammonium nitrate was based on a requirement for a more concentrated form of nitrogen than the ammonium sulphate hitherto used by Fisons in the manufacture of granulated compound fertilizers.

At the outset of the project, important decisions had to be taken concerning the source of ammonia, the types of nitric acid and ammonium nitrate plants to be installed and the physical form in which the ammonium nitrate was to be produced. Agreement was reached with the Shell Chemical Company to purchase nitrogen, part as ammonia and part in the form of nitric acid, from their projected plant at Shellhaven and this led to the choice of an adjacent site to facilitate the supply of liquid ammonia by pipeline. After careful consideration of capital and operating costs and of the corrosion problems arising from the use of salt water from the Thames for cooling purposes, the contract for the nitric acid plant was awarded to Chemical & Industrial International Ltd., of Nassau, Bahamas, which company was also awarded the contract for the ammonium nitrate plant. The final product is an aqueous 86% solution of ammonium nitrate, which is transported hot to compounding works in insulated road and rail tankers. The solution remains fluid above 85°C and is stored and transported at 120°C.

Site levelling at Stanford-le-Hope began in December 1956 and construction of the plant started in April 1957. Brian Colquhoun and Partners were appointed as civil engineering consultants. Sir Lindsay Parkinson & Co. Ltd. were responsible for the civil engineering work and Constructors John Brown Ltd., acting as associates of Chemical & Industrial International Ltd., carried out the installation of the process plants. The cost of the entire project is in excess of £4 million and this expenditure covers, in addition to the Stanford-le-Hope plant, the road and rail tanker fleet and additional plant at the compounding works to handle the ammonium nitrate. While the construction was in progress, the Production Manager and Shift Superintendents received their training in the U.S.A. on similar plants and the works staff of 130 were recruited.

Raw Materials

Liquid ammonia is pumped from Shellhaven to a 2,000 ton capacity insulated spherical tank where it is stored at 55 p.s.i.g. and 5°C, these conditions being maintained by means of a refrigeration unit. The ammonia supplied is 99.9% pure with a maximum oil content of 15 parts/million.

About 70% of the nitric acid required is produced at the works, while the remaining 30% is supplied from Shellhaven at 57.5% strength and is stored in a 100,000 gallon stainless steel storage tank.

Nitric Acid Plant

The Stanford-le-Hope nitric acid plant employs a modification of the Du Pont process whereby ammonia is catalytically oxidized by passing 10% ammonia/air mixture through platinum-rhodium gauze pade. The unit has a daily capacity of 223 tons (100% HNO_3) which is produced at a concentration of approximately 57.5% strength.

General view of the nitric acid plant.

Air is filtered and compressed to 120 p.s.i.g. in a 7,000-h.p. 9-stage rotary compressor, driven by two turbines, one steam and one gas, on a common shaft. The gas turbine operating on hot tail gas at 80 p.s.i.g. provides about two-thirds of the energy for the compressor, the steam turbine providing the balance. Evaporated ammonia at 100 p.s.i.g. is fed into the air-stream through a mixer and thence to the converter where the catalytic oxidation occurs. The reaction is exothermic and the catalyst is maintained at a temperature of about 940°C.

through a catalytic fume eliminator which converts oxides of nitrogen to innocuous nitrogen. Heat produced in this reaction is recovered as steam in a second waste-heat boiler. The purified tail gases, at a pressure of 80 p.s.i.g., pass through the gas turbine which forms part of the air compressor unit and are then vented. More than enough power to operate the plant is recovered by the gas turbine and steam turbines, surplus steam from the latter being passed on to other sections of the works.

The process is operated continuously,

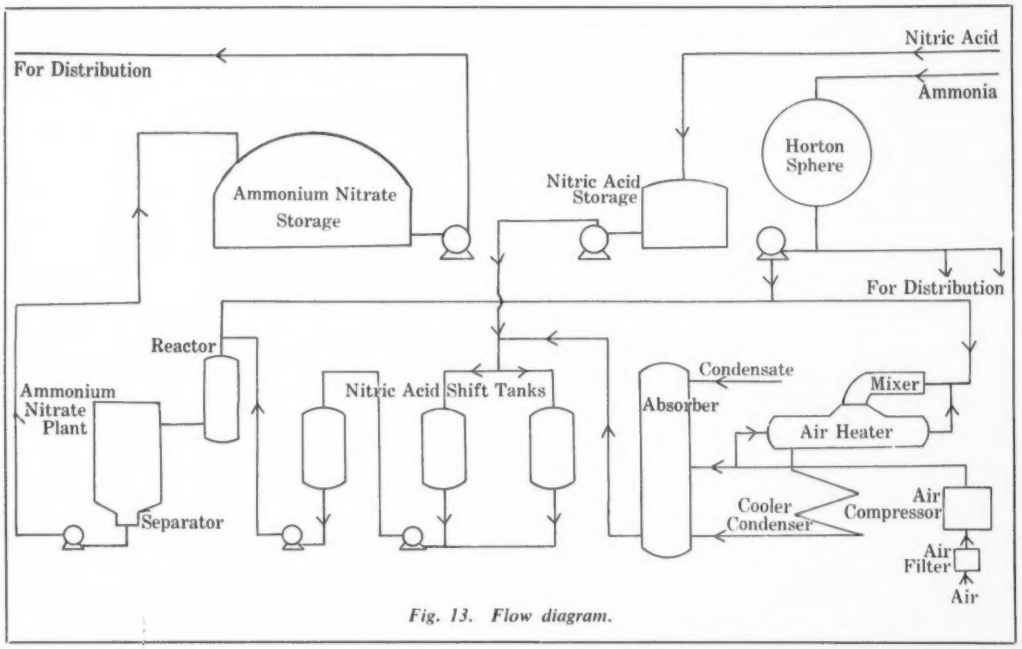


Fig. 13. Flow diagram.

The hot gases containing oxides of nitrogen are first cooled in a series of heat exchangers and then in a waste heat boiler, final cooling taking place in a serpentine cooler sprayed with water. The cold gases are passed into a bubble-cap absorption tower, where the oxides of nitrogen are absorbed to form nitric acid. After bleaching by a stream of secondary air at the base of the column the acid is fed continuously to storage. As the gases leaving the absorption tower contain oxides of nitrogen they are mixed with fuel gas to reduce the oxide concentration and passed

except for a short shutdown every three weeks for replenishment of the platinum-rhodium catalyst. A minimum nitric acid yield of 92.5% efficiency is guaranteed. The plant is fully instrumented and will shut down automatically and safely should any variations from the desired operating conditions occur.

A feature of this unit is its compactness, the total area it occupies being only 1,200 square yards. The air compressor and its ancillaries, the converter and the instrument control panel are housed in a two-storey building, while the rest of the plant is in the open.

Ammonium Nitrate Plant

The ammonium nitrate plant at Stanford-le-Hope employs the Stengel process, developed by the Commercial Solvents Corporation of New York. The reactor in this unit is a stainless steel tube packed with stainless steel rings, with the mixing equipment in the top section. Nitric acid is pumped through a heater into the mixer of the reactor where it meets a stream of ammonia vapour. The mixture passes down through the reactor where sufficient heat is developed to boil off most of the water contained in the nitric acid. Ammonium nitrate solution and steam from the base of the reactor flow through a separator from which the ammonium nitrate is pumped to storage through heated stainless steel pipes.

The process is operated continuously with a minimum guaranteed ammonium nitrate yield of 98% efficiency and accurate control of operating conditions is ensured by a high degree of instrumentation

Daily Plant Requirements

Ammonia from Shellhaven	143 tons
Nitric acid from Shellhaven	100 tons (100% HNO_3)
Cooling water (make up)	4,000 tons
Refinery gas	5,000 therms
Town water	100,000 gallons
Electric power	24,000 KwH
Steam for boilers	110 tons

Plant Capacities

Nitric acid	223 tons per day (100% HNO_3)
Ammonium nitrate	400 tons per day

Storage

In addition to the storage tanks for ammonia and nitric acid supplied from Shellhaven, three 40,000 gallon storage tanks are provided for nitric acid made on the site.

Ammonium nitrate solution is stored in two insulated tanks, one of 1 million gallons and the other of ½-million gallons capacity. Each tank is kept at 120°C by external heaters through which the solution is circulated.

Storage Capacities

Ammonia	2,000 tons
Nitric acid	220,000 gallons (800 tons 100% HNO_3)
Ammonium nitrate	1,500,000 gallons (8,000 tons NH_4NO_3) (800 tons 100%)

Transport

Ammonium nitrate solution is despatched both by rail and road to Fisons' fertilizer compounding works in various parts of the country. A fleet of 15 specially-built road tankers each of 2,400 gallons capacity supplying six compounding factories is operated under contract by Road Services (Caledonian) Ltd., loading and delivery being on a 24-hour basis. Eight such tankers can be filled in an hour at a gantry with four loading points. Two special articulated vehicles are also provided for conveying liquid ammonia to the compounding works as required.

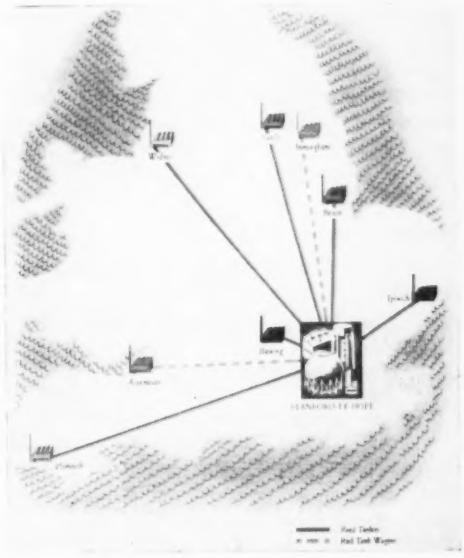


Fig. 14. Fisons fertilizer plants receive ammonium nitrate from Stanford-le-Hope by road and rail tank wagons.

British Railways, using 45 Fison-owned rail tankers, each with a capacity of 3,300 gallons of ammonium nitrate solution, designed for a maximum speed of 70 m.p.h., and fitted with vacuum brakes provide a regular scheduled express service to Messrs. Fisons' works at Immingham and Avonmouth. Each train, consisting of 15 tankers, can be loaded in 4-5 hours. A special tanker to take liquid ammonia can be attached to the train as required.

The ammonium nitrate solution is transported at 120°C and with the freezing point of the 86% solution at 85°C, an ample margin is provided by the temperature of the solution as filled to prevent crystallization en route. The tank cars are, however, provided with steam coils to cover unforeseen delays on the journey.

Ancillary Services

The boiler house at the new plant contains four oil-fired boilers, each with a rated capacity of 17,250lbs. steam per hour at 212°F, operated at a pressure of 200 p.s.i.g. Waste combustion gases discharge through a brick stack 150′ high. Boiler feed water is supplied by a Permutit hydrogen ion starvation base exchange water treatment plant installed in an annexe to the boiler house. For normal operation of the plant, the steam requirements can be met by one boiler only, supplemented by by-product steam from the nitric acid plant. The remaining boilers being required for starting up the nitric acid unit following a shutdown. For this purpose, the steam supplied to the turbine of the acid plant compressor is superheated to 540°F by means of an oil-fired Urquhart superheater.

Thames water for cooling purposes is piped to the site from Shellhaven, but a cooling tower, a 5 cell induced draught unit, is used to keep water usage to a minimum. The incoming water is first treated with aluminium sulphate to flocculate suspended matter, then allowed to settle in a conical concrete sedimentation tank, from the bottom of which sludge is withdrawn from time to time.

The clarified water flows to a concrete inflow pond from which it is circulated to the process plants by two variable speed 6,000 g.p.m. centrifugal pumps. Return water from the process flows via a flume to an adjacent cooling tower pond from which the warm water is pumped over the cooling tower by two variable speed 6,000 g.p.m. centrifugal pumps.

Purge water from the cooling system, sludge from the settling tank and surface water from the site are collected in a concrete estuary pond and discharged into the river.

Cooling Water Storage Capacities

Cooling tower pond	240,000 gallons
Inflow pond	40,000 gallons
Estuary pond	90,000 gallons

Administrative and other buildings on the site include an office block, a canteen, a laboratory and a plant office, workshops and stores, instrument and carpenters' shops, an experimental building, a locomotive shed and two sub-stations for power distribution.

The whole plant has been designed with a view to expansion and only 25 acres of a total site area of 63 acres have so far been developed.

Conclusion

With the commissioning of the Stanford-le-Hope plants, Fisons Limited will be in a position to provide their compounding works with some 140,000 tons of ammonium nitrate annually, representing about 15% of United Kingdom supplies of fertilizer nitrogen. The primary output of nitrogen is supplied by the Shell Chemical Company Limited and based on Shellhaven whose ammonia plant with an annual capacity of 85,000 tons N, provides 24% of the current level of N production in the United Kingdom. Fisons' decision to extend their activities from phosphate fertilizers, of which they are the largest manufacturers in the United Kingdom, to converting bought in primary nitrogen to a nitrogen fertilizer is prompted in part by the requirement for compounding material with a higher nitrogen content as well as the desire for a greater measure of independence of nitrogen supply. Hitherto, Fisons controlled only one-half of the ammonium sulphate output of Nitrogen Fertilizers Limited, amounting to about 10,000 tons N annually, and purchased the remainder of their requirement principally from Imperial Chemical Industries Limited.

This development occurs at a time when the demand for compound and complex fertilizers is accelerating. In this connection it is significant that whilst the consumption of compound fertilizers in the United Kingdom has risen by 18% since 1952/53, the quantity

	N	*P*	*K*	*Total*	*Product*
1952/53	125,228	108,597	187,987	501,812	1,891,099
1953/54	131,790	200,780	209,930	542,500	1,938,526
1954/55	138,240	203,416	218,612	560,268	1,932,875
1955/56	163,830	229,671	256,342	649,843	2,164,118
1956/57	163,898	224,959	267,338	656,195	2,140,137
1957/58	178,177	236,319	288,591	702,987	2,230,327

of nitrogen used in these fertilizers has risen by 42% within the same period, but even so this increase is less pronounced than the greater supply of phosphate and potash nutrient.

The growing consumption of compound fertilizers in the United Kingdom has been accompanied by a trend towards the use of higher analysis material. While the average plant food content of compound fertilizers sold in the United Kingdom has risen from 26.54% in 1952/53 to 31.52% in 1957/58, their average nitrogen content has only increased from 6.62% to 7.99% within the same period. The provision by Fisons of the substantial new volume of high analysis material can be expected to accelerate this trend.

UREA AT MODDERFONTEIN

The Stamicarbon Process

THE FIRST UREA PLANT in Africa will come into operation in February 1960 at the Modderfontein works of African Explosives and Chemical Industries Ltd., about 10 miles from Johannesburg. These works have a capacity of 62,000 tons of nitrogen, now used principally in the manufacture of nitric acid and ammonium nitrate.

The new plant is being built by Messrs. Werkspoor N.V. of Amsterdam, Holland, to the process design of another Dutch firm, Stamicarbon N.V. of Geleen, and will have a daily capacity of 325 short tons of uncoated urea prills. Stamicarbon, a subsidiary company of Staatsmijnen in Limburg, the Dutch State Mines, has access to all technical experience and patents of its parent organisation which operates a 150 ton per day urea plant at Geleen. The Stamicarbon process is being incorporated in two other plants now under construction, as Werkspoor N.V. are building a 140 ton per day unit for Société Carbochimique at Tertre in Belgium and a 70 ton per day unit is being erected in Trinidad for Federation Chemicals Limited.

There are two variations of this process, the once-through and the partial recycle arrangements, and it is the partial recycle system which is to be used at Modderfontein, where the un-recycled ammonia will be used for neutralizing nitric acid in the manufacture of ammonium nitrate. The raw materials for urea production, liquid anhydrous ammonia and carbon dioxide gas, will be supplied from other sections of the Modderfontein works. Impurities in the carbon dioxide gas will be removed by passing it through iron oxide boxes. The liquid ammonia will be supplied at 150 p.s.i.g. and, being substantially pure, will contain no contaminants other than traces of oil and catalyst dust which will be removed by filters. While much attention is at present being focussed on total recycle processes, it is the once-through or partial recycle systems which would still appear to be most suitable for use in large, integrated fertilizer plants. The process to be used at Modderfontein is a notable example of the latter.

Reaction

The purified carbon dioxide gas and liquid ammonia compressed to 200 atmospheres and mixed in a molar ratio of between 1:4 and 1:5 are fed into a 2-stage reactor where the temperature is maintained at 175°C. The heat of the exothermic reaction is used to produce steam in the first stage of the reactor in which ammonium carbamate is formed. In the second stage part of the ammonium carbamate is converted to urea.

Recirculation

On leaving the reactor the mixture of urea, unconverted ammonium carbamate, excess ammonia and water is reduced to about 20 atmospheres. At this intermediate pressure, the excess ammonia is recovered and recycled to the liquid ammonia feed pump and some ammonium carbamate from the reaction product is recycled to the reactor.

The urea solution, still containing unconverted ammonium carbamate, is decom-

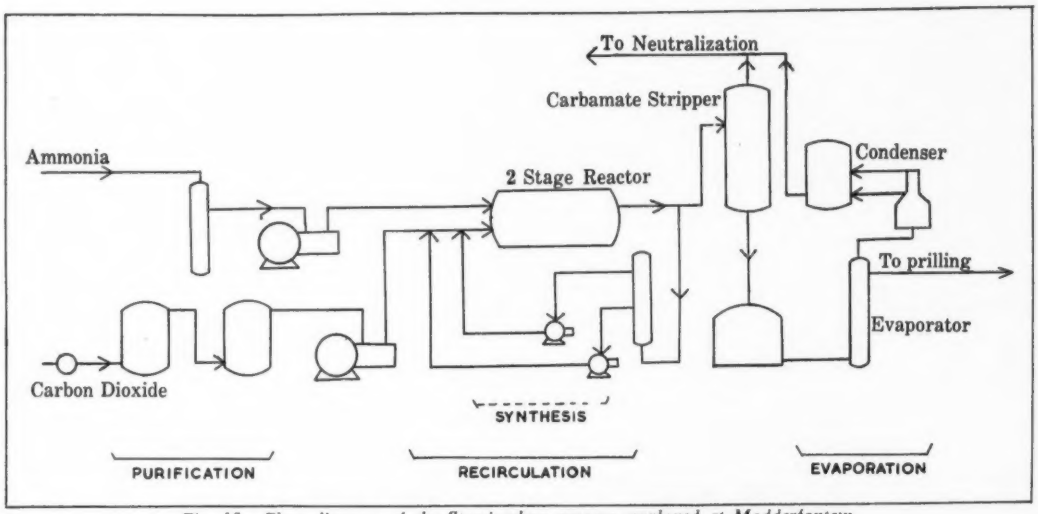


Fig. 15. Flow diagram of the Stamicarbon process employed at Modderfontein.

pressed to 1.2 atmospheres, the pressure required for ammonia recovery by neutralization with nitric acid, and is heated to 90-100°C. The ammonium carbamate is dissociated and the gas formed, containing ammonia, carbon dioxide and a small quantity of water vapour, is sent to the ammonium nitrate plant.

Evaporation

The purified urea solution is concentrated in a two-stage evaporator from which the water vapour, containing small amounts of ammonia, is condensed in surface condensors. The uncondensable gases and the ammonia gas, which have not been dissolved in the condensate, are extracted from the condensors by steam ejectors. The ammonia gas from the condensor, together with ammonia gas from other sections of the plant (buffer tanks, etc.) is then treated with the condensate at atmospheric pressure and is thereby absorbed. The solution obtained is sent to a desorber from which ammonia is sent to the ammonium nitrate plant.

Prilling

The urea melt, on leaving the second stage of the evaporator, is sprayed into a prilling tower in which it solidifies. A rake at the bottom of this tower throws the product to a belt conveyor and a bucket elevator brings the prills to the top of the dressing building. Oversize prills are separated on a screen, undersize prills being removed by dusting. The separated lumps and fines are dissolved in water and the resulting urea solution is returned through filters to the evaporators.

The prills of standard size are cooled in a fluidized bed, weighed and then bagged or moved to bulk storage. Prills produced by this process are outstanding because of their uniformity; their particle size is essentially in the range of 1-2.4 m.m. and they have a comparatively high crushing strength favouring storage in bulk, uncoated and without air conditioning. This is an important advantage as coating would detract from their quality. Processing at this stage is such that biuret and moisture in the product do not exceed 1% and 0.3% respectively, whilst the nitrogen content is not less than 46%.

Corrosion

Although specific details have not been disclosed, the plant makers are likely to use stainless steel, such as type 18-8, for the lining of the synthesis reactor; this material will probably also be used in the pressure reduction valves and the low pressure section of the plant.

A notable feature of the Stamicarbon process is its patented method for checking corrosion in the synthesis reactor by injecting small quantities of oxygen which inhibits the corrosive action of the carbamate on the stainless steel.

Construction

According to modern practice, all operating equipment is being built in an open steel structure, the floors of the plant being of concrete with a layer of asphalt. The main structure will have three floors at 16′ 5″, 31′ 2″ and 45′ 11″ level respectively.

The dressing equipment, comprising elevators, screens, dust removers, cooler and weighing machines are being housed in a closed steel structure adjoining the storage shed. The prilling tower, built entirely of concrete, has a height of 114′ 10″.

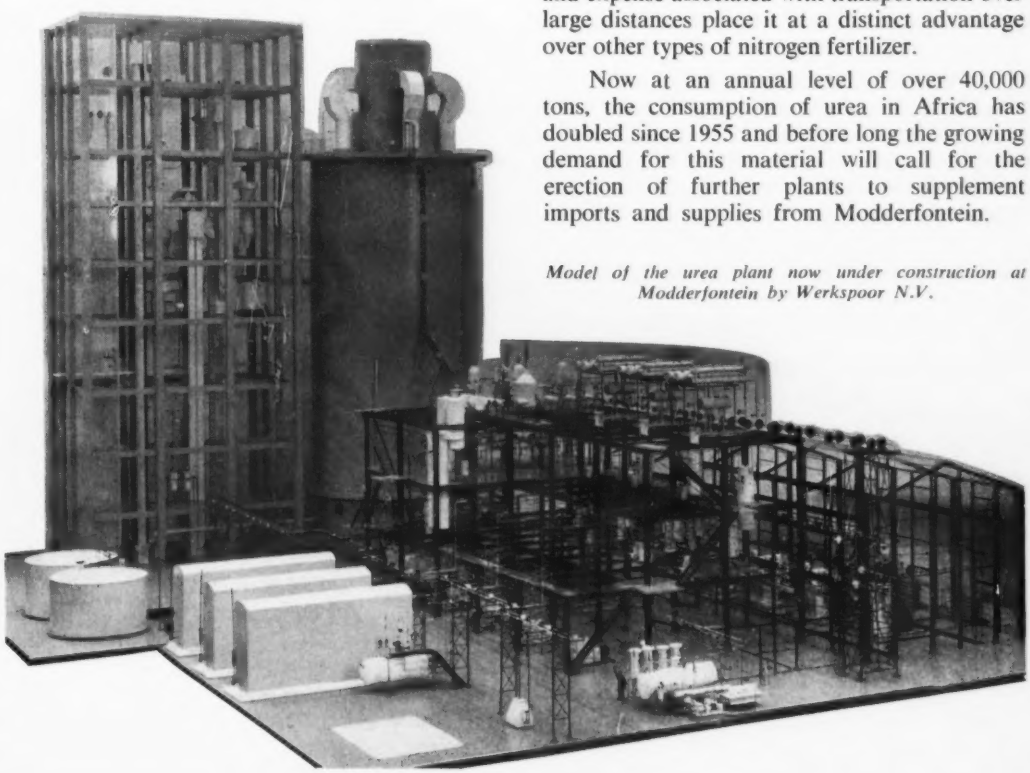
Control of the plant is fully automatic. The control room, 69′ x 39′ 8″, will be pressurized with air to keep it free of dust and is situated in the centre of the main structure on the ground floor.

Conclusion

It is perhaps, significant that the American firm of W. R. Grace & Co. should have chosen the Stamicarbon process for the plant now under construction in Trinidad for their subsidiary, Federation Chemicals Ltd. W. R. Grace themselves operate a large urea plant using the Pechiney total recycle process at Memphis, Tenn., where there would be an inadequate market for ammonium nitrate, sulphate or phosphate as a by-product of urea. In Trinidad, where conditions permit the production of ammonium sulphate and the use of a once-through or partial recycle system, the Stamicarbon process has been adopted from several alternatives. It can especially be commended for a comparatively low rate of corrosion and for the high quality of its product.

There can be little doubt that the initiative taken by African Explosives and Chemical Industries Ltd. in erecting a urea plant in Africa will be handsomely rewarded. Not only will there be a large and expanding market for urea on several crops, notably sugar cane, cotton, tobacco and coffee, but the problems and expense associated with transportation over large distances place it at a distinct advantage over other types of nitrogen fertilizer.

Now at an annual level of over 40,000 tons, the consumption of urea in Africa has doubled since 1955 and before long the growing demand for this material will call for the erection of further plants to supplement imports and supplies from Modderfontein.



Model of the urea plant now under construction at Modderfontein by Werkspoor N.V.

INDIA

By 1963 India's synthetic nitrogen industry will be one of the five largest in the world if the production targets set by the Planning Committee of the Ministry of Agriculture are attained. These provide for the production of three-quarter million tons N by 1963/64, whilst consumption of fertilizer nitrogen is intended to rise by annual increments of 100,000 tons N to one million tons N by 1965/66.

India started manufacturing nitrogen fertilizers on a substantial scale with the inauguration in 1951 of the State-owned and managed Sindri fertilizer plant. The following table shows India's nitrogen balance since 1951 and her projected production and requirements until 1964 :—

	Production	Consumption (000 tons N)	Imports
1951/52	10.7	50.9	20.7
1953/54	64.9	84.9	25.5
1955/56	79.9	144.6	37.6
1957/58	81.9	184.0	94.0
1959/60	100.0*	400.0	300.0†
1961/62	300.0*	600.0	300.0†
1963/64	750.0*	800.0	50.0†

* Planned. † Requirements.

In 1957/58 actual consumption almost reached the target of the Second Five-Year Plan. The expansion to a level of 600,000 tons N within three years foreseen in the Third Five-Year Plan indicates that domestic production will supply only half this requirement and that provision will be made for a temporary but very steep rise in imports. The capacity provided by five large plants now in the planning stage or actually under construction will amount to some 460,000 tons N by 1963/64 and it is clear that if the production target for that year is to be reached work will have to start within two years on the installation of an additional 300,000 tons of capacity.

PRODUCTION

In 1958 the Sindri works in Bihar State, the only major nitrogen plant operating in India, had an annual capacity of 70,000 tons of nitrogen based on the use of coke-oven gas, but extensions recently completed at this plant have increased its capacity to 117,000 tons of nitrogen a year. The additional production will be in the form of 148,000 tons of ammonium sulphate nitrate and 24,000 tons of urea.

Two smaller synthetic nitrogen plants are in operation. With an annual capacity of 10,000 tons of nitrogen, the plant operated by Fertilizers & Chemicals Travancore (Private) Ltd. manufactures ammonium sulphate and ammonium phosphate, while the Mysore Chemicals & Fertilizer's works has an annual capacity of 1,000 tons of nitrogen in the form of ammonium sulphate. Plans to double the capacity of these two plants are under consideration. In addition, it is planned to raise the output of by-product nitrogen, now at an annual level of 6,000 tons, to 16,000 tons a year by 1963.

Neyveli

The second large nitrogen plant to be built in India is intended to go into operation in 1960 at Neyveli in Madras State. This plant will have an annual capacity of 70,000 tons of nitrogen based on the use of lignite and production will be in the form of 152,000 tons of urea using a total recycle process. Among the plant constructing firms competing for the £15 million contract are Società Montecatini and the Japan Plant Association.

Nangal

Various problems, including a shortage of foreign exchange and complications arising

from a heavy water project to be built on an adjacent site, have delayed the construction of the lime ammonium nitrate works at Nangal in East Punjab. Most of these difficulties have now been solved and the plant, involving an outlay of £5.2 million, is due for completion in April 1960. Much of the equipment for the Nangal plant, which will have an annual capacity exceeding 80,000 tons of nitrogen based on the use of coal, is being supplied and erected by Saint Gobain.

Rourkela

Construction of a large nitrogen fertilizer plant at Rourkela, 280 miles west of Calcutta, has been delayed as a shortage of foreign exchange held up the completion of the steelworks and coking plant which are to supply its raw materials. Financed by West German interests, the steelworks and coking plant were opened in January, and using 1.6 million tons of coal a year have a daily capacity of 1.68 million cubic metres of coke-oven gas. By-products of this important plant will eventually include ammonia, tar, benzene and sulphur.

The ammonia plant at Rourkela is to be built by Friedrich Uhde G.m.b.H. of Dortmund, an affiliate of Farbwerke Hoechst A.G. Due to start production in March, 1962, it will have an annual capacity of 80,000 tons of nitrogen a year produced in the form of lime ammonium nitrate.

Trombay

The fifth major nitrogen fertilizer plant to be erected in India is to be built at Trombay near Bombay and close to the refineries of the Standard Vacuum and Burmah Shell Oil Companies. The two oil companies have agreed in principle to supply refinery waste gases to the nitrogen plant and it is planned to make it possible to use fuel oil as an alternative source of hydrogen.

Tenders are now being invited for this project, worth nearly £18 million, and it is intended that the plant should have a capacity of 90,000 tons of nitrogen a year. While it is assumed that the entire plant will be able to switch from refinery gases to fuel oil and vice-versa, a three unit design has been recommended to enable one-third, two-thirds or the entire plant to use either raw material.

Approximately half the ammonia produced is to be used in the manufacture of 97,500 tons of urea annually, the balance being used in the manufacture of 254,000 tons of nitrophosphate a year. The production of the latter would entail imports of phosphate rock to the value of nearly £1 million a year.

The Trombay plant, for which foreign aid is assured, is due to come into operation in 1963 and it is estimated that its annual production of 90,000 tons of nitrogen will afford a saving of about £8½ million in foreign exchange. It is expected that the cost of production at Trombay will be lower than at other nitrogen plants in India.

Rajasthan

In addition to the five major plants at Sindri, Neyveli, Nangal, Rourkela and Trombay with a combined capacity ammounting to 437,000 tons of nitrogen a year, several other plants are under consideration by both the state and private interests. A committee has been set up to study the economies of fertilizer manufacture in Rajasthan, Andra Pradesh and Madhya Pradesh while another committee has been appointed to investigate the possibilities of the use of natural gas for fertilizer production at Naharkatiya in Assam.

The Rajasthan project is expected to be the first to materialise but certain difficulties have still to be overcome before construction of the ammonium sulphate plant can begin. The entire reserves of best quality gypsum containing from 86% to 87% calcium sulphate found at Jamsa and estimated at 30 million tons have been allocated to Sindri and although large quantities of gypsum are found in the western states, none is available with a calcium sulphate content higher than 85%.

It is not yet known what types of fertilizers are planned for production at Andra Pradesh and Madhya Pradesh but it is understood that Foster Wheeler Corporation are erecting an ammonium chloride plant with an annual capacity of 10,000 tons of nitrogen a year for Sahn Jain Ltd. of Calcutta.

The two principal by-product nitrogen plants in India will be located in West Bengal at the Durgapur Iron Works and the Bhilai steel plant and it is planned that together they should make available 7,200 tons of nitrogen a year in the form of ammonium sulphate.

Model of the Sindri Fertilizer Factory. Note map in background showing principal destinations.

Urea in India

It can be expected that several more nitrogen fertilizer projects will be announced within the next two years and that they will include the erection of substantial urea capacity. Consumption of urea in India is now at an annual level of 30,000 tons of nitrogen and while the plants at Sindri, Neyveli and Trombay will be able to meet a demand four times greater than this, it can be reasonably expected that urea requirements will rise to 150,000 tons of nitrogen by 1965. Plants employing the "once through" process and manufacturing ammonium nitrate, sulphate or phosphate as a by-product of urea would appear to be the most likely to find favour.

Conclusion

The Indian Government's desire to achieve a rapid expansion of her nitrogen fertilizer industry is prompted as much by her need to increase food production as by her wish to broaden this industrial sector. Present plans commit her to a capital expenditure of over £50 million on nitrogen plants with a capacity of 460,000 tons of nitrogen within the next five years. In support of this heavy outlay, much of which is dependent upon foreign aid, it has been pointed out that domestic production will make supplies of nitrogen available at an appreciably lower cost than the present price of imported material and the following data have been quoted :—

Production Cost per ton of Nitrogen	
Sindri	£86
Nangal	£65
Trombay	£59
Imported	£100

It is significant that this major expansion programme for the nitrogen industry in India comes at a time when a substantial measure of over-capacity is evident in several parts of the world. It has been suggested that in the present state of the Indian economy, when excessive demands from all industrial sectors are made upon limited capital resources, an expanding nitrogen import programme may be more advantageous, especially if it were encouraged by price concessions on the part of the traditional nitrogen exporters.

As shown above, existing plans provide for the continuation of nitrogen imports into India, but there is little doubt that the level of consumption could be stimulated significantly if supplies of imported nitrogen became available at prices which compared favourably with those of the domestic output.

THE CHEMICO UREA PROCESS

EQUIPPED with a total ammonia recovery system and affording a high rate of conversion of ammonium carbamate to urea, the Chemico 6 : 1 process was developed soon after the Second World War by the Chemical Construction Corporation of New York and was first used commercially in 1952. Employed in 10% of the total world urea capacity now in operation, this process is to be used in a number of major plants at present under construction, including a 106,000 ton per year unit at Fenchuganj in East Pakistan and extensions which will raise the capacity of the installations of the Nihon Gas Chemical Industries at Niigata from 29,000 to 62,000 tons a year.

Feed

Liquid ammonia and gaseous carbon dioxide are fed to the reactor in a molar ratio of 6 : 1, the ammonia being 99.5% pure, with an oil content of less than 10 ppm and normally supplied at a pressure of 250 p.s.i.g. The maximum purity is desirable in the carbon dioxide feed, although sulphur compounds, the only contaminants likely to have a serious effect on the process, may be removed if necessary before the reactor stage. The carbon dioxide should be supplied at a few inches above water gauge pressure.

Reaction

The reaction takes place at a temperature of 180°C and a pressure of approximately 300 atmospheres with the ammonium carbamate formed being converted to urea at a rate of between 76 and 78%. This high rate of conversion is obtained by the use of a substantial excess of ammonia in the feed and as under these conditions the reaction is autothermal, it is unnecessary to have heat exchanger surfaces inside the synthesis column.

Ammonia Recovery

On leaving the reactor the mixture of urea, unconverted ammonium carbamate, ammonia and water is throttled and passed to a separator where 84% of the excess ammonia is driven off under pressure, condensed, liquified and returned to the reactor. The urea, ammonium carbamate—only about 24% of the original quantity—and water are passed to the carbamate stripper where the ammonium carbamate is decomposed by heat to ammonia and carbon dioxide, whilst the urea and water are now available for processing to prills or crystals. The ammonia and carbon dioxide from the carbamate stripper are passed to an absorber where the carbon dioxide is absorbed in a monoethanolamine solution. The unabsorbed ammonia is compressed, condensed and returned to the reactor in liquid form.

The monoethanolamine solution, saturated with carbon dioxide, is passed to a carbon dioxide desorber where it is regenerated, the resultant carbon dioxide is then vented or

RAW MATERIAL REQUIREMENTS PER TON OF UREA

	6 : 1 feed ratio		2.5 : 1 feed ratio	
Feed	*Partial recycle*	*Full recycle*	*Partial recycle*	*Full recycle*
Ammonia	0.97	0.58	0.84	0.58
Carbon Dioxide	1.06	0.78	0.91	0.78
Off-Gas Available				
Ammonia	0.39	—	0.26	—
Carbon Dioxide	0.28	—	0.13	—

UTILITY REQUIREMENTS PER TON OF UREA

6 : 1 feed ratio*

	prills produced	*crystals produced*	*additional for total recycle*
Power	180 KwH	193 KwH	35 KwH
Steam			
150 p.s.i.g.	4,000 lbs.	4,800 lbs.	3,000 lbs.
Cooling Water at 85°F ...	23,300 I. galls.	23,300 I. galls.	16,600 I. galls.

* Pending patent applications details for the 2.5 : 1 feed ratio are not available but operating costs may be assumed at about 10% less than for the 6 : 1 process.

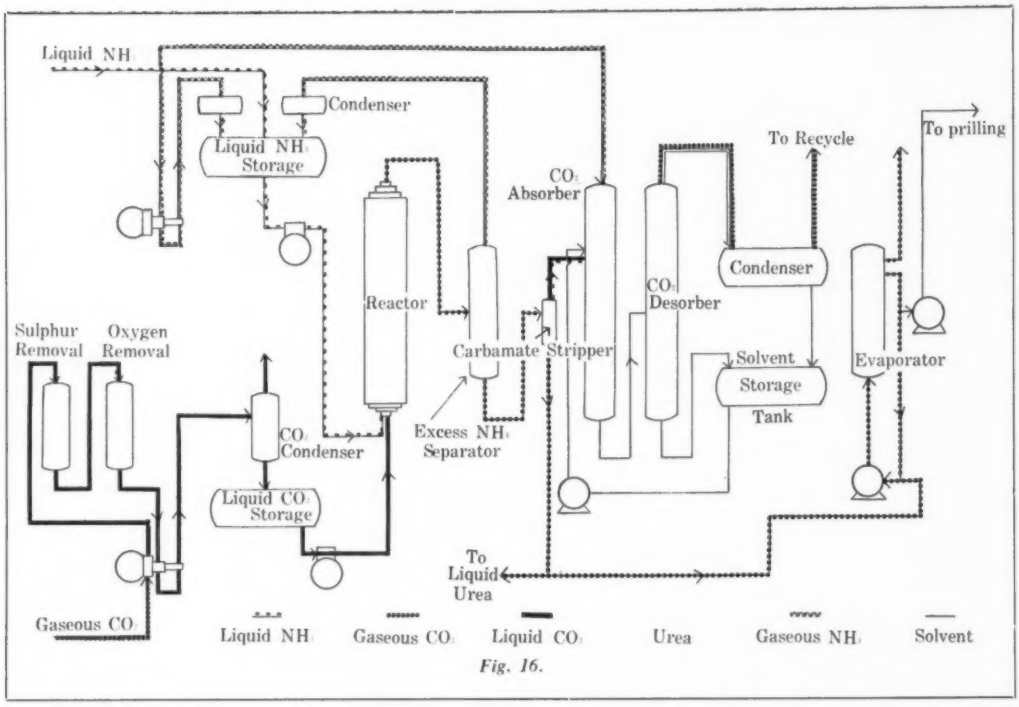


Fig. 16.

recycled to the reactor. The regenerated amine solution is returned to the upper part of the absorber for further use.

Low Ratio Feed

A recent development of the Chemico process is the use of a feed ratio to the reactor of 2.5 parts of ammonia to 1 part of carbon dioxide. Whereas hitherto the disadvantages of such low feed ratios have appeared to outweigh the advantages, the Chemical Construction Corporation have now developed a low ratio system employing an improved plant for carbamate solution recycle. As this 2.5 : 1 version of the Chemico process is now the subject of patent applications, full details are not yet available, but it is expected that capital and operating costs will be about 90% of those for the 6 : 1 feed ratio system. The 2.5 : 1 feed ratio is to be employed in a 30 ton per day plant now being installed in the United States for the Cooperative Farm Chemicals Co. at Lawrence, Kansas.

Partial Recycle System

Both the 6 : 1 and 2.5 : 1 versions of the Chemico process may be used in a partial recycle system where the decomposed ammonia and carbon dioxide gases are not recycled on leaving the carbamate stripper but are used in the manufacture of by-product ammonium salts—ammonium sulphate, nitrate or phosphate. In this system the excess ammonia separated from the reaction product is still recycled to the reactor as in the total recycle versions of the process.

Evaporation and Prilling

The mixture of urea and water from the carbamate stripper is passed into a wiped surface falling film evaporator which produces a 99.5% solution. This may then be used as a solution, crystallized or prilled.

Analysis of Crystals Produced by the Chemico Process

Nitrogen	46.0% min.
Biuret	0.3 - 0.4%
Total Moisture	0.1 - 0.25%
Ash	35.0 ppm max.
Iron	2.0 ppm max.
Colour (APHA)	10.0 max.
Turbidity (APHA)	15.0 max.

When prilling the solution is passed from the evaporator to the top of the prilling tower as rapidly as possible to minimise biuret formation. In one plant the evaporator has been mounted on top of the prill tower itself, but although this reduces biuret formation, maintenance and operating costs are increased. Biuret contents of less than 0.6% have been achieved with evaporators at ground level and a maximum of 1% is guaranteed.

Analysis of Prills by the Chemico Process

Nitrogen	46.0% min.
Biuret	1.0% max.
Total Moisture	0.5% max.
Colour	13

Foliar Grade

For use of urea on vegetables, flowers and young fruit trees as a solution where it is desirable for the biuret content to be kept below 0.2%, Chemical Construction Corporation have developed a system, currently the subject of patent applications, which yields foliar grade urea containing less than 0.05% biuret.

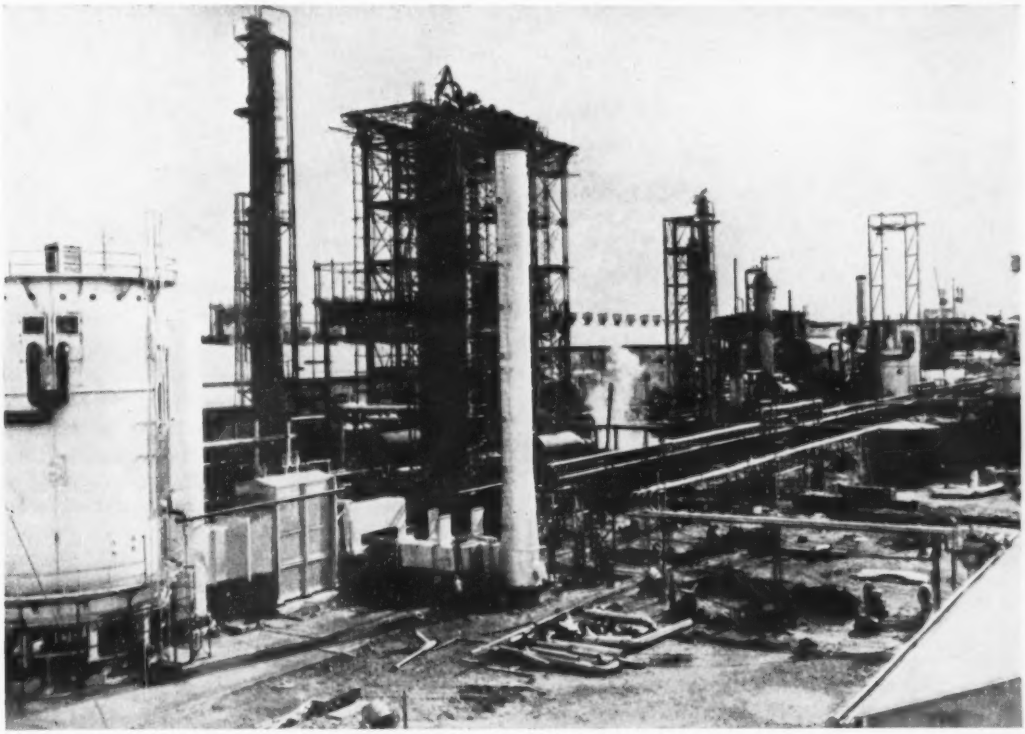
Analysis of Foliar Grade Urea by the Chemico Process

Nitrogen	46.0% min.
Biuret	0.05% max.
Total Moisture	0.1 max.
Ash	35.0 ppm max.
Iron	2.0 ppm max.
Colour	10.0 max.
Turbidity	15.0 max.

This grade is also suitable for use in the manufacture of high grade moulding resins where the biuret content may be critical.

Materials and Corrosion

The reactor used in the Chemico process is normally lined with silver or a commercially available alloy steel. Silver, electro-plated to a Monel liner, imparts the minimum impurity to the reaction product and affords the maximum



Nihon Gas Chemical Industries. Construction work on the extension to the urea plant at Niigata.

resistance to corrosion but initially, at least, is appreciably more expensive than the alloy steel.

The alloy steel has given equally satisfactory results in operation an exhibits a high degree of resistance to corrosion. A lead lining is recommended for the ammonia separator, aluminium normally being used for the low pressure equipment and pipelines handling urea and carbamate solutions.

Conclusion

The high rate of conversion of carbamate to urea afforded by the Chemico process is achieved largely by the use of a substantial quantity of excess ammonia in the reactor. The excess ammonia helps to control the temperature of the reaction as it absorbs some of its heat. The initial capital outlay and plant operating costs are reduced by the simplicity of design, not only in the reactor but in the method of recovery of excess ammonia in liquid form without additional compression or refrigeration. At least 84% of the excess ammonia is recoverable.

Where economic conditions indicate a reduced capital outlay and the production of ammonium salts in addition to urea, the partial recycle system using either the 6 : 1 or 2.5 : 1 feed ratio may in many cases prove advantageous. Where a total recycle system is to be employed, the high overall rate of ammonia conversion—97%—and its simplicity and economy of operation make the Chemico process appear particularly attractive. In addition, total recovery of carbon dioxide can be achieved when necessary with little extra cost.

In common with other urea manufacturing systems, the employment of the Chemico process still calls for a substantial capital outlay but it affords a high degree of efficiency particularly advantageous to producers in competitive markets and at a time when the growth of urea consumption is in no small measure related to its price.

THE PECHINEY UREA PROCESS

DEVELOPED by the Compagnie Pechiney at St. Auban in France, the Pechiney urea process is installed at present in two large plants in the United States which have a combined capacity of 145,000 tons a year and account for 10% of the total world capacity. Built by Foster Wheeler Corporation, the Pryor, Oklahoma, plant of John Deere & Co. came into operation in 1954 with a capacity of 90,000 tons a year. The Memphis, Tennessee, plant of W. R. Grace & Co., also built by Foster Wheeler Corporation and completed in 1956, has an annual capacity of 55,000 tons. The capacity of this plant will be doubled when extensions now in progress are completed this year.

The salient feature of the Pechiney process is that unreacted ammonia and carbon dioxide are recycled to the synthesis reactor as a suspension of ammonium carbamate in oil. The use of an inert mineral oil is an important factor in minimising corrosion, the principal problem associated with operation of a urea plant.

Reactor

Carbon dioxide is compressed to 3,200 p.s.i.g. and traces of sulphur are removed in a desulphurization tower packed with activated carbon. The carbon dioxide is then heated to 260°C. by passing through a gas-fired preheater and small traces of oxygen are removed in a tower packed with a copper catalyst.

Liquid ammonia is compressed to 3,200 p.s.i.g. and passed through a steam-heated exchanger where its temperature is raised to 260°C. With the purified carbon dioxide stream and the recycled suspension of ammonium carbamate in oil, it is then fed into a lead-lined reactor.

Ammonia and carbon dioxide react to form ammonium carbamate which, together with recycled ammonium carbamate, is partially converted to 1 mol. of urea and 1 mol. of water. The urea synthesis is carried out at 180°C. and 3,000 p.s.i.g. After a given residence time in the reactor, a mixture of urea, oil, water and ammonium carbamate is continuously released from the top of the reactor

column, decompressed to between 4.2 and 5.6 atmospheres and then passed to the carbamate stripper.

Carbamate Stripper

The product of the reactor enters the top of the ammonium carbamate stripper column where it comes into contact with a rising stream of ammonia, carbon dioxide and water vapour. The stream preheats the falling liquid and aids in the decomposition of ammonium carbamate to ammonia and carbon dioxide. The stripper bottoms are heated in a forced circulation reboiler which supplies heat for the decomposition of the ammonium carbamate.

The stripper bottoms containing urea, oil and water are then cooled by flashing and sent to the decanter, where oil is continuously separated off the top layer and aqueous urea passes from the bottom layer to the evaporation section. On leaving the evaporator, the urea can be crystallised, prilled or processed as a solution.

The stripper overhead containing ammonia, carbon dioxide and water vapour and the oil decanted from the stripper bottoms are sent to oil-gas reactors, where the ammonia and carbon dioxide react to form a finely dispersed suspension of ammonium carbamate in an oil slurry. The oil-gas reactors are horizontal cylinders containing a number of horizontal shafts fitted with vertical plates for atomizing the oil. They are cooled to within 24-40°C. in order to obtain the ammonium carbamate in a finely dispersed state.

The suspension of ammonium carbamate in oil contains 35-50% solids, the viscosity being sufficiently low for pumping by pipeline to the synthesis reactor at the same pressure as the original feed gases. The light paraffin oil used in this process is insoluble in water, does not react with the compounds of the synthesis reaction and has a low vapour pressure at the synthesis temperature.

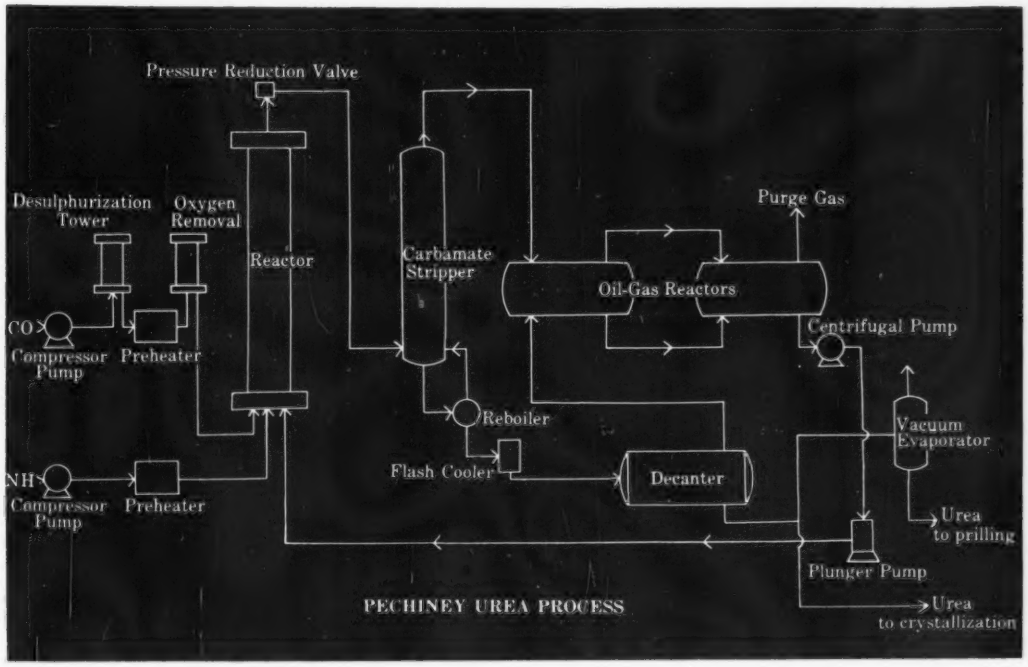
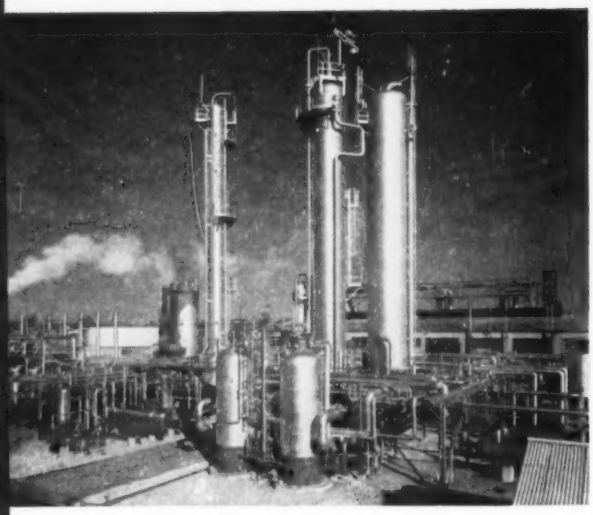


Fig. 17.



CO_2 scrubbing section at J. Deere & Co's. Pechiney urea.

Pechiney Process Oil

Specific gravity (API)	35.5
Viscosity SSU	
at 100°F	75.0
at 210°F	35.5
Colour (ASTM)	1 minus
Acid Number	0.01

On leaving the oil-gas reactors, the slurry of oil and ammonium carbamate is picked up by a centrifugal pump and delivered to a high pressure plunger pump which drives it back to the synthesis reactor.

The raw material and utility requirements per ton of prilled urea of a plant with an annual capacity of 20,000 tons are as follows :—

Carbon dioxide	.58	ton
Ammonia	.76	ton
Process oil	1.0	gallon
Fuel gas	220,000	B.T.U.
Electricity	177	kwh
Steam	5,600	lbs.
Cooling water at 85°F	33,000	gallons

Conclusion

The principal advantages of the Pechiney process are that it affords a relatively low operating cost and a low rate of corrosion. That it is not as yet widely used is no doubt due to the comparatively high capital cost involved, but experience gained in operating Pechiney type plants in the United States is expected to result in increased efficiency with lower capital outlay.

Although originally conceived and developed as a total recycle system, the Pechiney process can be modified and adapted as a once-through system if conditions prohibit the higher capital investment required for a total recycle plant and if there is a market for ammonium sulphate, nitrate or phosphate as a by-product. Where a total recycle plant is required, however, the system of recycling ammonia and carbon dioxide as a solution of ammonium carbamate in oil has several advantages. The serious problems of corrosion and erosion are reduced by the wetting effect of the oil which forms a protective film on the walls of the reactor column. The oil also provides a simple means of absorbing the exothermic heat of the reaction and, as the reactor products cool to the temperature required for carbamate stripping, heat is recovered thereby reducing the quantity of steam required for heating the process. The use of oil also results in slightly lower power requirements.

An interesting feature of the design is the use of lead for the reactor lining. This has been made possible because in the Pechiney process little water is recycled to the reactor and thus a satisfactory rate of conversion of ammonium carbamate to urea can be obtained at a moderate temperature and pressure—about 180°C. and 3,000 p.s.i.g. respectively. Another important feature of the process is that it can be operated at 50% of capacity without loss of efficiency.

Experience gained in operating the Memphis, Tennessee, plant has enabled W. R. Grace & Co.'s engineers to carry out simplifications and improvements to the process and operating technique. The decision of W. R. Grace & Co. to co-operate with Compagnie Pechiney and the process licencees, Foster Wheeler Corporation, to make available this experience should render this process more attractive than hitherto to potential urea manufacturers.

Expansion of the Nitrogen Industry in Hungary

THE SECOND Five-Year Plan (1956-60) provided for a 25% increase in investment in the Hungarian chemical industry over the actual expenditure for 1950-54 and the greater part of this allocation was devoted to the expansion of nitrogen production.

There are at present two nitrogen plants operating in Hungary, the Pét Nitrogen Works at Varpalota and the Kazincbarcika Works in the North-East. Production of nitrogen at the Pét Works, established before the Second World War, has been at a level of 12,000 tons N a year mostly in the form of ammonium nitrate. Manufacture of ammonium nitrate at these works, which in 1938 had exceeded 25,000 tons, was less than 5,000 tons in 1947 but had risen to 59,000 tons in 1950, and has since been maintained at this level. Extensions to these works are now in progress and it is planned to connect them by pipeline with Lovaszi in the Zalaegerszeg oilfields now being developed in south-western Hungary.

The Trans Sajo Chemical Works at Kazincbarcika, better known as the Borsod Chemical Combine, are situated in North-Eastern Hungary and were opened in 1955. Production of nitrogen fertilizers at Kazincbarcika, based on the use of coal and in the form of ammonium sulphate and ammonium nitrate, was at a level of 30,000 tons a year until 1958 when extensions to the plant raised this to 50,000 tons annually. With the help of credits from the Soviet Union the capacity of this plant is being still further increased to exceed 13,000 tons N a year.

The most important project in the current expansion programme is the nitrogen fertilizer and plastics plant under construction at Tiszapalkonya in the North-East. These works are to use natural gas piped from Rumania and are intended to produce 280,000 tons of nitrogen fertilizer a year, in addition to lacquers and plastics as secondary products. It is understood that the capacity of the Tiszapalkonya plant will be 48,000 tons N a year and that ammonium nitrate will be the principal fertilizer manufactured.

Work on the Hungarian section of the gas pipeline which began in December 1957 was completed with the Rumanian section in the summer of 1958. The pipeline was planned to bring the Tiszapalkonya works into operation in 1959 and was built at a cost of some $2 million using 11,000 tons of 12" diameter piping supplied by the Soviet Union. Serious delays have, however, occurred and although much of the machinery has already been delivered from the Soviet Union, only the lacquer plant will be working by the end of this year. The fertilizer plant will be ready in 1960 or 1961 and the plastics plant is not expected to come into operation until 1963. Meanwhile the gas, mostly high purity methane, is being used for other purposes.

Production of nitrogen in Hungary has increased by 390% since 1938 and by 150% since 1949 while that of nitrogen fertilizers has risen by 320% and 115% within the same periods. Substantial though these increases may be, it is highly improbable that the targets of the Second Five-Year Plan will be achieved. The delays caused by the uprising in 1957 have disrupted the programme and several installations will not be completed in time.

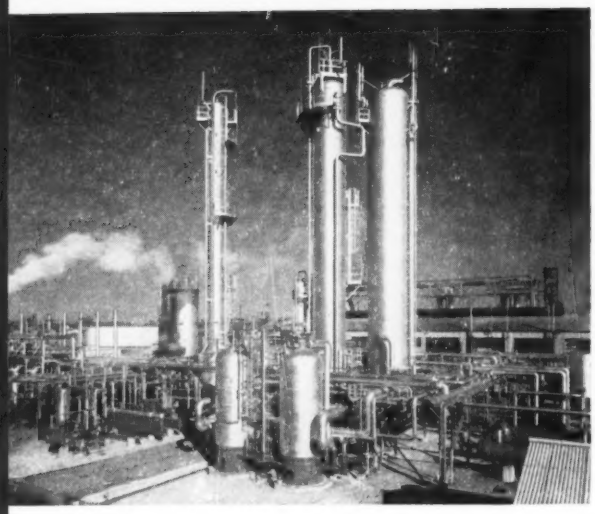
Nitrogen Production *(thousand metric tons)*

	1938	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*
Ammonia	8.2	15.6	20.7	23.7	25.1	24.2	23.2	22.1	33.0	27.9	40.0
Nitrogen fertilizers	26.9	53.0	62.4	65.5	61.7	59.3	64.8	62.5	94.4	79.7	113.8
N content of fertilizers	5.5	10.9	12.8	13.4	12.6	12.1	13.3	12.8	19.5	16.4	23.4

Targets of the Second Five-Year Plan
(thousand metric tons)

	1955	*1960 (plan)*
Nitrogen fertilizers	62.5	435
Plastic materials	2.7	11.6

Despite the possibility of further delays in the expansion programme, there can be little doubt that Hungary is on the point of permanently establishing herself as a net exporter of nitrogen fertilizers. At the same time her consumption of technical nitrogen, in particular for the manufacture of plastics, can be expected to grow rapidly.



CO_2 scrubbing section at J. Deere & Co's. Pechiney urea.

Pechiney Process Oil

Specific gravity (API)	35.5
Viscosity SSU	
at 100°F	75.0
at 210°F	35.5
Colour (ASTM)	1 minus
Acid Number	0.01

On leaving the oil-gas reactors, the slurry of oil and ammonium carbamate is picked up by a centrifugal pump and delivered to a high pressure plunger pump which drives it back to the synthesis reactor.

The raw material and utility requirements per ton of prilled urea of a plant with an annual capacity of 20,000 tons are as follows :—

Carbon dioxide	.58	ton
Ammonia	.76	ton
Process oil	1.0	gallon
Fuel gas	220,000	B.T.U.
Electricity	177	kwh
Steam	5,600	lbs.
Cooling water at 85°F	33,000	gallons

Conclusion

The principal advantages of the Pechiney process are that it affords a relatively low operating cost and a low rate of corrosion. That it is not as yet widely used is no doubt due to the comparatively high capital cost involved, but experience gained in operating Pechiney type plants in the United States is expected to result in increased efficiency with lower capital outlay.

Although originally conceived and developed as a total recycle system, the Pechiney process can be modified and adapted as a once-through system if conditions prohibit the higher capital investment required for a total recycle plant and if there is a market for ammonium sulphate, nitrate or phosphate as a by-product. Where a total recycle plant is required, however, the system of recycling ammonia and carbon dioxide as a solution of ammonium carbamate in oil has several advantages. The serious problems of corrosion and erosion are reduced by the wetting effect of the oil which forms a protective film on the walls of the reactor column. The oil also provides a simple means of absorbing the exothermic heat of the reaction and, as the reactor products cool to the temperature required for carbamate stripping, heat is recovered thereby reducing the quantity of steam required for heating the process. The use of oil also results in slightly lower power requirements.

An interesting feature of the design is the use of lead for the reactor lining. This has been made possible because in the Pechiney process little water is recycled to the reactor and thus a satisfactory rate of conversion of ammonium carbamate to urea can be obtained at a moderate temperature and pressure—about 180°C. and 3,000 p.s.i.g. respectively. Another important feature of the process is that it can be operated at 50% of capacity without loss of efficiency.

Experience gained in operating the Memphis, Tennessee, plant has enabled W. R. Grace & Co.'s engineers to carry out simplifications and improvements to the process and operating technique. The decision of W. R. Grace & Co. to co-operate with Compagnie Pechiney and the process licencees, Foster Wheeler Corporation, to make available this experience should render this process more attractive than hitherto to potential urea manufacturers.

Expansion of the Nitrogen Industry in Hungary

THE SECOND Five-Year Plan (1956-60) provided for a 25% increase in investment in the Hungarian chemical industry over the actual expenditure for 1950-54 and the greater part of this allocation was devoted to the expansion of nitrogen production.

There are at present two nitrogen plants operating in Hungary, the Pét Nitrogen Works at Varpalota and the Kazincbarcika Works in the North-East. Production of nitrogen at the Pét Works, established before the Second World War, has been at a level of 12,000 tons N a year mostly in the form of ammonium nitrate. Manufacture of ammonium nitrate at these works, which in 1938 had exceeded 25,000 tons, was less than 5,000 tons in 1947 but had risen to 59,000 tons in 1950, and has since been maintained at this level. Extensions to these works are now in progress and it is planned to connect them by pipeline with Lovaszi in the Zalaegerszeg oilfields now being developed in south-western Hungary.

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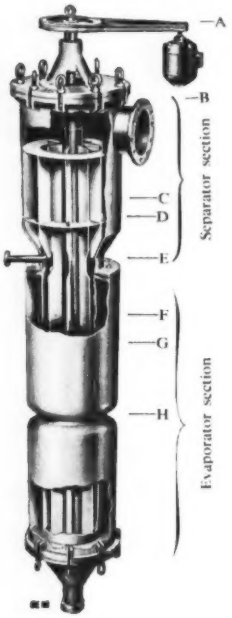
THE EVAPORATION OF UREA SOLUTIONS

THE UREA PROCESSES that have been applied industrially with success have many features in common. In essence, the synthesis of ammonia and carbon dioxide to urea via ammonium carbamate is chemically straightforward so much so that, as far as can be ascertained from published information in this respect, the various methods differ only in detail. Fundamentally on exit from the reactor the product stream—at considerable pressure usually about 200 atms.—consists in various proportions of unreacted gases, urea and ammonium carbamate from which the urea is separated in as pure a state as possible, whereas up to 100% of the excess gases or carbamate may be recycled to the autoclave.



A Rotor drive

B Bearing and shaft seal

C In the separator section the rotor effects removal of droplets and foam by centrifugal action

D Baffles for intercepting and returning droplets thrown off by the rotor

E Feed inlet

F Heating wall

G Rotor. The blades, separated by minimum distance from the heating wall, produce a thin layer of high turbulence in the evaporator section

H Heating jacket

I Outlet for unevaporated product

Fig. 18.

The physical-chemical bases of the process have been given most fully by Fréjacques (1), who also outlines what is now known as the "Pechiney" process. More recently Chenoweth (2) has also shown how all processes are fundamentally similar. The most recent review of the various processes, as far as information is available, is from an American source (3). It is evident that the greater part of urea produced as a solid is now in the more convenient form of "prills" and not crystals as formerly. This is a simplification but it does mean that urea must be converted into a molten state at as near 100% purity as practicable.

The following account concerns the last stage of the several process steps between the reaction melt at high pressure and the pure molten urea at atmospheric pressure. In preceding stages most of the excess gases have been removed and there is left a 75-80% aqueous solution of urea with relatively small amounts of dissolved gases, the precise composition of which depends on the process used. This is now concentrated to about 99% + T.S. under conditions which prevent as far as possible heat damage and the formation of biuret ($NH_2CONH_2CONH_2H_2O$) since this has been shown to be injurious to crops in most fertilizer applications. To this end the time during which the urea solution is held at temperatures above 110°C is reduced to an absolute minimum, but since urea melts at 131°C and biuret formation of less than 0.5% is considered desirable, difficulties arise.

One device which meets the requirements of this evaporation is the LUWA thin-layer evaporating machine, specifically designed for the rapid and uniform treatment of heat-sensitive materials. The function of this apparatus is illustrated by Fig. 18. The vertical evaporator tube is surrounded by a heating jacket; the separator is located at the top. A rotor on a vertical axis produces a thin layer of high turbulence in the evaporator section, while in the separator section it ejects any droplets or foam carried over.

The urea solution introduced above the heating jacket, distributed evenly over the entire circumference of the evaporator and

(1) M. Fréjacques — Chimie et Industrie **60** 22 (1948).
(2) G. E. Chenoweth — Chem.Eng.Prog. **54** (4) 55 1958.
(3) Anon. — Chem.Eng., Jan. 26, 1959.

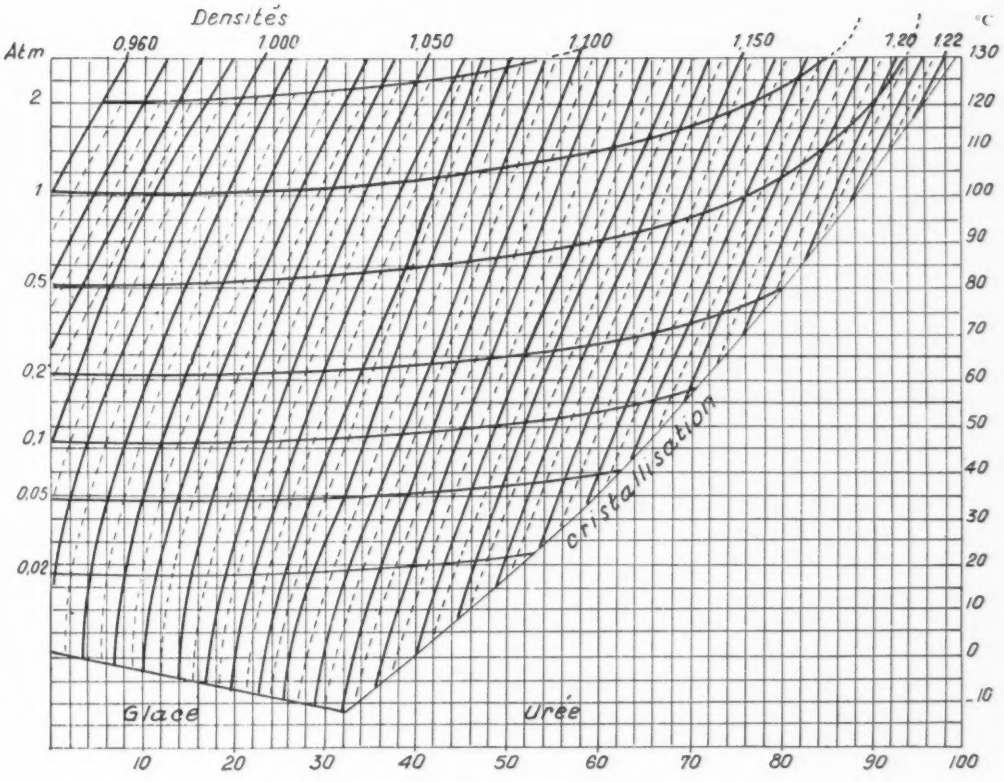


Fig. 19. Density and vapour pressure of urea solutions.

instantly spread by the rotor blades (turning at about 12 metres/sec. peripheral speed) as a film of great turbulence across the whole heating surface. The film flows downwards under the influence of gravity, while the heat applied to the heating jacket at the same time causes intensive evaporation. In a few seconds and after only one passage through the apparatus, the unevaporated portion of the product reaches a conical outlet at the lower end of the evaporator and is eliminated. The countercurrent of vapours, on the other hand, flows upwards into the separator, where the high-speed rotor frees it from all liquid particles, and it then passes through an outlet branch into the condenser.

The evaporation can be carried out in this machine and the biuret formation held at a sufficiently low figure that even after subsequent prilling the final biuret content does not exceed a value that can be safely tolerated for such sensitive fertilizer applications as leaf sprays.

It is relevant in respect of biuret formation that the greater the quantity present in the molten product fed to the prilling tower, the greater the increase in passage through the latter, so that the lowest level of polymerisation during the evaporation stage is desirable.

In determining the actual capacity of the LUWA machine, it is important that the temperature difference should be as high as can be tolerated either by using a high steam pressure in the heating jacket or by as low a temperature as possible inside the machine. The machine is normally designed for a work-

ing pressure of 10 atms. steam, although mechanically there is no objection to higher working pressures. The limitation lies rather in the thickness of the heating wall. Since the larger machines have an internal diameter of nearly 1,500 mms. and are about 8 m. long, the wall thickness may be such that its conductivity, when fabricated of stainless steel, is a major resistance to heat transfer.

The evaporating pressure inside the apparatus is to some extent determined by the necessity of maintaining the urea product at a temperature of at least 132°C in order to keep it molten. In practice, however, it has been shown that a second factor must be taken into account, namely, that if the temperature of the molten urea is maintained as low as would be practicable, somewhere in the passage of the urea solution through the apparatus it will pass through a zone where crystallisation takes place, i.e., the equilibrium temperature of the urea solution corresponding to the absolute pressure is too low and crystallisation occurs. This occurrence can be deduced from Fig. 19, taken from the paper by Fréjacques, from which it will be seen that to prevent crystallisation of urea from water in the region 75% to 100% T.S., an operating pressure of at least 0.3 atm. is required and, in fact, during evaporation in the machine this pressure is raised to about 350 mms. to give an adequate margin under all operating conditions. Of course, a little further down the apparatus more water will have been removed, the temperature will rise and these crystals will melt. However, the presence of a crystalline slurry along the walls of the apparatus considerably increases the power needed to maintain adequate agitation in the evaporating film.

It is also of interest that the need to maintain the lowest possible biuret content, i.e., the highest possible purity of urea, aggravates the crystallisation problem. Fig. 20 shows this trend clearly.

As in most circumstances a biuret content of 1% would be unacceptably high in the molten urea, certain practical limitations are imposed on the operation of this machine. It has been found that an overall heat transfer coefficient of about 700 kg.cals/m²/hr./°C is achieved

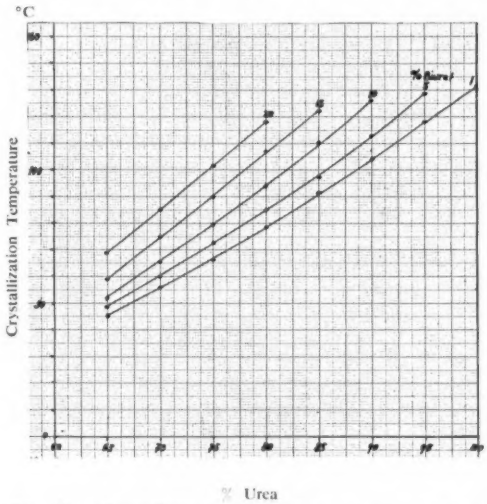


Fig. 20. Crystallization temperature of urea solutions showing various biuret content.

and that the evaporative capacity is the equivalent of about 230 kilos/hr./m² of water-free urea.

It is also important to arrange the evaporator in such a manner that the pipework between its outlet and the entry into the prilling tower should be as short as possible. The advantage of keeping the residence time in the evaporator as low as possible would be nullified if, afterwards, the urea remained molten in pipework at a high temperature for an appreciable period. For this reason it has been stated by the operators of two urea processes that the evaporator should be placed on top of the prilling tower in spite of structural and operational problems that this may involve (3).

The LUWA apparatus offers distinct advantages in this important stage of urea manufacture and it is now installed in most of the successful industrial processes. About 4,000 tons per day of product is made in LUWA evaporating machines installed in 80% of the world urea capacity now in operation.

New Billingham Installations Inspected

MORE THAN 400 agricultural merchants, fertilizer agents of Imperial Chemical Industries Ltd., visited the Billingham works on 21st April and saw some of the new plant recently installed at this the largest fertilizer factory in the British Commonwealth and one of the largest in the world. Among the installations on view were the new concentrated complete fertilizer (C.C.F.) plant and the Kay-Nitro plant, both commissioned in the autumn of 1958. The largest granular fertilizer plant in Great Britain, the new C.C.F. unit employs ammonium sulphate and monammonium phosphate, both manufactured at Billingham, and imported muriate of potash. The monammonium phosphate plant employs imported phosphate rock which is treated with sulphuric acid yielding a liquor containing phosphoric acid from which the solid gypsum by-product is removed by filtration. The clear phosphoric acid is neutralised with ammonia to form monammonium phosphate for use in the C.C.F. plant. Ammonium sulphate manufacture at Billingham is based on the use of anhydrite and is at an annual level of 750,000 tons. The old C.C.F. granulation plant has now been modified to manufacture KayNitro, a fertilizer made by a process in which ammonium nitrate solution is concentrated by steam heating in a vacuum and then mixed with ammonium sulphate and muriate of potash, at an estimated annual rate of 350,000 tons. The operation of several process stages was shown on closed circuit television.

In an address to the guests, Sir Alexander Fleck, K.B.E., F.R.S., Chairman of I.C.I., reminded them that with the opening in 1958 of the Leith works of Scottish Agricultural Industries Ltd., the whole output of the new plant at Billingham would be available to markets south of the border. Sir Alexander reminded his audience that in addition to the new plant at Billingham, a new nitric acid unit and a modified Nitro-chalk plant were in operation at Heysham resulting in an increase of about £15 million in the Billingham Division's investment in fertilizer production. A reference was made to the new 60,000 tons per annum ammonia synthesis unit completed at Billingham and the first in Great Britain using fuel oil as a raw material.

In reviewing the progress and expansion of nitrogen fertilizer manufacture by I.C.I., the Chairman recalled that synthetic ammonia was first produced at Billingham in 1923, that in 1929 ammonium sulphate production exceeded 400,000 tons and Nitro-chalk manufacture started, the first granulated concentrated complete fertilizer being produced two years later. Sir Alexander attributed the ability of I.C.I. to overcome problems created by the depression in the 1930's and a serious world surplus of nitrogen to the introduction in 1935 of the import duty of £4 a ton on nitrogen fertilizer and to the diversification of production at Billingham. This helped to ensure that at the outbreak of war in 1939 adequate supplies of nitrogen were available for both fertilizer and munitions production. Sir Alexander expected that United Kingdom nitrogen consumption, which had risen from a pre-war figure of 60,000 tons a year to 165,000 tons in 1946, would exceed 325,000 in 1959. Whilst expecting competition in the fertilizer market to increase, he was confident about the ability of I.C.I. to meet this challenge and stressed the potential consumption of nitrogen on grassland, pointing out that about one-half the acreage of temporary grassland and three-quarters of the permanent grassland in the United Kingdom still received no nitrogen fertilizer. Referring to the report of the Monopolies Commission, expected later this year, Sir Alexander pointed out that while major costs—such as wages, coal and freight —have increased by 42% since 1952, fertilizer prices have risen by only 21%. Both Sir Alexander Fleck and in his reply, Colonel J. F. Crampthorn, President of the National Association of Corn and Agricultural Merchants, emphasised the close co-operation between I.C.I. management and the company's agents.

current events

CANADA

New Urea Capacity

The second urea plant in Canada and the first in Western Canada will be built for the Consolidated Mining and Smelting Co. of Canada at Turner Side near Calgary. Involving a capital outlay of $5 million, the new unit will have an annual capacity of 36,000 tons and is to be completed by the summer of 1960. The Turner Side works, on the Bow river, have an annual capacity of 85,000 tons N based on the use of natural gas from Turner Valley and production is at present in the form of prilled ammonium nitrate. It is probable that the plant will employ a once-through process as the excess can be readily used in conventional ammonium nitrate manufacture.

The first urea plant in Canada was commissioned in the spring of this year by Cyanamid of Canada Ltd. at Hamilton, Ontario. Using raw materials supplied as by-products of the adjacent steel mills of Dominion Foundries & Steel Ltd., the plant built by Chemical Construction Corp. has an annual capacity of 66,000 tons of urea.

It has recently been announced that Cyanamid of Canada, whose ammonia capacity of about 52,000 tons has until now been based on imported coal, is engaged on a conversion programme which within twelve months will convert operations to the use of natural gas. Summing up the $5 million programme, Dr. L. P. Moore, President of Cyanamid, expected that the urea and ammonia production at the new Hamilton Bay plant, coupled with the increased volume of production at Welland, will be sufficient to supply all the foreseeable needs of Ontario and Quebec for nitrogenous fertilizers.

Now at an annual level of 37,000 tons N, Canada's consumption of fertilizer nitrogen has risen by only 12% since 1952 but can be expected to increase at an appreciably faster rate within the next five years. Not only will Canada be able to meet most of this demand from domestic production but she is rapidly improving her position as an exporter of nitrogen fertilizers to the important United States market and other parts of the world.

EIRE

Ammonium Nitrate from Peat

The Minister of Industry and Commerce has instructed Ceimici Teoranta, the Irish State Chemical Co., to prepare a report on proposals for a nitrogen fertilizer works at Shannon Bridge in County Offaly and to submit a plan for the erection of this plant.

The possibility of establishing a nitrogen fertilizer works in Eire was first considered seriously 12 years ago and plans had almost been completed for the construction of a plant to produce ammonium sulphate from coal, but as the demand for ammonium nitrate is now greater the latest scheme envisages the manufacture of this fertilizer from "turf." It is understood that the new plant will have an annual capacity of 100,000 tons of ammonium nitrate and will involve a capital outlay of between £7 and £8 million. The Government has approved in principle to provide funds for this project but is also offering tax concessions to foreign investors. In the meantime plans are also advancing for the establishment of a nitrogen plant at Cobh where the output will be in the form of ammonium sulphate.

There is a strong case for the establishment of nitrogen fertilizer production in Eire as some £2½ million is spent each year on imported material. Consumption of nitrogen is now at an annual level of 18,000 tons, but it is considered by the Government that Irish farmers should use three times this quantity. The proposed plants at Shannon Bridge and Cobh would make it possible to double the present rate of consumption. The Shannon Bridge plant if completed by 1962 would repay its initial cost within six years.

EAST GERMANY

Large Scale Expansion at Leuna-Werk

East Germany's nitrogen capacity will be substantially increased by extensions to the VEB Leuna-Werk Walter Ulbricht which will be carried out during the next six years.

Formerly one of the key works of the I.G. Farbenindustrie, Leuna-Werk, near Magdeburg, and one of the largest nitrogen plants in the world, was heavily damaged in the Second World War. It has since been almost entirely rebuilt, but it was not until 1953 that production was restored to its pre-war level. This is now at an annual rate of over 300,000 tons of nitrogen and supplies more than 90% of East Germany's requirements of nitrogen fertilizers. Approximately half the ammonia manufactured at Leuna-Werk is converted to ammonium sulphate using gypsum, the remainder being used in the production of nitric acid, ammonium nitrate and urea.

It would appear that the extensions planned for Leuna-Werk will raise the nitrogen capacity of this plant by approximately one-third. They will involve the installation of additional capacity for the manufacture of urea, of which an estimated 8,500 tons was produced in 1958, and the re-building of the nitrating plant. Ammonium sulphate nitrate is to be added to the range of fertilizers manufactured at Leuna-Werk.

Other important features of the expansion programme are that a medium pressure process will be used in the hydrogenation units in place of the high pressure (250 atmospheres) process employed at present, thereby effecting a considerable saving in hydrogen, and that higher capacity synthesis units will be employed. A higher degree of automation will be incorporated into the plant and in several cases batch processes will be made continuous. The improvements planned also include the use of " fluid system " catalysts.

Modernization and extensions are also to be carried out at the smaller Stickstoffwerk Piesteritz and the present annual capacity of 20,000 tons of nitrogen is to be doubled by 1961.

By 1965 production of nitrogen in East Germany can be expected to exceed 450,000 tons a year, thereby doubling the pre-war level and representing an increase of 33% over the current rate of production. In addition to meeting her own growing agricultural and technical requirements, East Germany will be able to raise the volume of her exports of nitrogen fertilizers to other countries in Eastern Europe and to increase her competitive nitrogen supplies on the world market.

WEST GERMANY

Second Urea Plant

The Union Rheinische Braunkohlen Kraftstoff A.G. are to build a urea plant at Wesseling with an annual capacity of 25,000 tons. The new plant, due for completion in 1960, will be only the second of its kind in Western Germany and will use ammonia and carbon dioxide supplied from other sections of the Wesseling works. Ammonia capacity of Wesseling now exceeds 175,000 tons of nitrogen a year but as yet no fertilizer materials are manufactured there.

At present Badische Anilin und Soda Fabrik operates a urea plant at Oppau with an estimated annual capacity of 132,000 tons. As yet the consumption of fertilizer urea in Western Germany is negligible and much of the output of the Oppau plant is exported or used captively by B.A.S.F. in the manufacture of synthetic resins, but it is believed that this company is finding difficulty in expanding the technical urea market for its surplus urea production.

The output of the Wesseling plant is to be sold as fertilizer and as technical urea and it is likely that a large proportion will be exported.

GREECE

Progress of the Ptolemais Project

An agreement has been signed by which the United States Development Loan Fund will advance $12 million to assist in financing the $36 million nitrogen fertilizer plant to be built at Ptolemais near the Bodossakis lignite mines in northern Greece. The contract to build the plant has been awarded to a consortium comprising the Franco-Italian firm Ammonia-Casale and Friedrich Uhde G.m.b.H. of Dortmund and production is expected to start

in 1961. Based on the complete gasification of lignite the capacity of the Ptolemais plant will be more than 90,000 tons of nitrogen a year, equivalent to 350,000 tons of nitrogen fertilizers. The greater part of the production at the new plant will be in the form of ammonium sulphate but ammonium nitrate will also be manufactured. It is understood that the Greek Government's Agricultural Economic Planning Commission is considering a proposal to build an ammonium phosphate works in northern Greece.

Consumption of nitrogen fertilizers in Greece amounted to 37,400 tons in 1953/54 and to 67,300 tons N in 1957/58, an increase of 80%. The entire demand is at present met by imports and will continue to be until the Ptolemais plant is fully in operation. The Economic Planning Commission has recommended that until domestic production has been developed on an economic basis, the State subsidy for imported material should be maintained and that funds be made available for the construction of fertilizer warehouses at distribution centres.

ISRAEL

Fertilizers & Chemicals Ltd. to Double Capacity

The capacity of the nitrogen fertilizer plant operated by Fertilizers & Chemicals Ltd. at Haifa, at present 10,000 tons of nitrogen a year, is to be doubled by 1960 and it is planned to raise it thereafter to 26,000 tons a year. Production is at present largely in the form of ammonium sulphate but in future a greater part will be in the form of ammonium nitrate. A nitric acid unit with an annual capacity of 22,000 tons of 58% strength acid was completed at the end of 1958 and is now in operations whilst orders have recently been placed for equipment for increased production of both liquid and granulated fertilizer.

Another installation recently commissioned is a £1½ million carbide plant built for Mayer Chemical Industries at Petah-Tikvah with an annual capacity of 10,000 tons. Initially most of the carbide produced at this plant will be used in the manufacture of acetylene but eventually it will also be used to make calcium cyanamide for use as a fertilizer and in the manufacture of plastics.

Consumption of nitrogen fertilizers in Israel rose from 11,400 tons N in 1953/54 to 14,000 tons N in 1957/58, an increase of nearly 23%. Even though consumption may continue to rise steadily, the extensions to the Haifa works alone should enable Israel to meet virtually all her requirements for several years to come.

Extension to the Ammonia plant at Haifa.

PERU

Second Synthetic Nitrogen Plant

Negotiations are in progress between the Government-controlled Cia Administradora de Guano and the Japan Plant Association for the erection of a nitrogen fertilizer plant at the port of Chimbote, where Peru's new iron and steel works has recently been put into operation.

It is understood that the Japan Plant Association will supply the equipment and some technical assistance for the proposed plant which is estimated to involve a capital outlay of over $16 million. Using fuel oil or refinery waste gases as the raw material the Chimbote plant is to have an annual capacity

of 20,000 tons of urea and 40,000 tons of ammonium sulphate. A $2.3 million loan has been granted by the U.S. Import-Export Bank to the Japan Plant Association which has obtained approval by the Japanese Finance Ministry for the purchase of machinery for the urea plant.

Electric power for the steel works is supplied by the Cânón del Pato hydroelectric installation located in the Cordillera Negra, inland from Chimbote, with an installed capacity of 50,000 K.W.'s. This capacity will have to be considerably raised to meet the requirements of the new nitrogen plant and it is doubtful if the latter will be completed within two years. It is expected that the urea plant will employ a once-through process.

The Chimbote installation will be the second synthetic nitrogen plant to be built in Peru. The first, completed at Callao early this year, has an annual capacity of 25,000 tons of fertilizer grade ammonium nitrate, 5,000 tons of refined ammonium nitrate for use as explosive, 1,500 tons of concentrated nitric acid, 15,000 tons of ammonium sulphate and 1,000 tons of ammonia (50% N). Based on fuel oil as the source of hydrocarbon, this plant was designed and built by Soc. Montecatini S.A. for Fertilizantes Sinteticos S.A. and involved a capital outlay of $10 million, of which 40% was provided by Peruvian funds, the balance being advanced by Italian and Swiss interests.

The erection of synthetic nitrogen plants in Peru has been encouraged by depletion of the guano deposits. Guano production has fallen from a record total of 332,187 tons in 1956 to its present level of 160,000 tons a year, necessitating imports of some 40,000 tons of nitrogen fertilizers from the United States.

RUMANIA

Capacity to be Raised

The development of the Rumanian nitrogen industry starts with the important advantage of a well-established supply of natural gas of high purity, and in fact Rumania became one of the first countries in the world to use natural gas in the manufacture of ammonia on a commercial scale when the Diciosanmartin plant was commissioned in 1937. Production is at present confined to this plant with a capacity of 4,000 tons of nitrogen a year, employing the Fauser-Montecatini process to produce hydrogen by sodium chloride electrolysis and the reforming of natural gas. Two large plants are now being built at Fagaras and Roznov. With an annual capacity of some 30,000 tons of nitrogen in the form of ammonium nitrate, the Fagaras plant is due for completion early next year. Originally designed for an annual capacity of 62,000 tons of nitrogen, the Roznov plant is to be capable of producing over 80,000 tons a year when completed in 1962 or 1963 and it is expected that ammonia produced at this plant will be used in the manufacture of ammonium nitrate, ammonium sulphate and urea. Production of nitrogen at both plants will be based on the use of indigenous natural gas which has a methane content of between 99.5 and 99.8%.

Consumption of nitrogen fertilizers in Rumania does not at present exceed 15,000 tons of nitrogen a year, but in common with other Communist countries in Eastern Europe the government is calling for a greatly increased use of chemical fertilizers. An important objective is the expansion of the sugar beet crop to meet domestic sugar demand and to provide an exportable surplus, and it is expected that this project will account for a large proportion of the nitrogenous fertilizer output of the Fagaras and Roznov plants.

UNITED STATES

Ketona to Employ New Ammonium Prilling Process

Work on the installation of facilities to produce 75 tons per day of prilled ammonium nitrate and lime ammonium nitrate is nearing completion at the Ketona, Alabama, plant of the Ketona Chemical Corporation. Designed and built by the Chemical & Industrial Corporation, of Cincinnati, Ohio, the new units represent the second expansion of the Ketona works which will become the first plant in the south-east, and only the second in the United States, to manufacture lime ammonium nitrate.

Built in 1956, with an annual capacity of 45,000 tons of anhydrous ammonia by the Claude process, the Ketona plant was the first in the United States to operate exclusively on

coke-oven gas. Nitrogen is at present sold in the form of 50% strength ammonia, nitric acid and ammonium nitrate solutions.

The installations now being built at Ketona will employ a new prilling process developed by the Chemical & Industrial Corporation using a prilling tower with a height of only 50ft. instead of the 200ft. structure normally used. A falling film evaporator removes nearly all the water in the liquid ammonium nitrate before it is sprayed into the prilling section as an anhydrous melt of over 99.5% concentration. Pulverised limestone (100%, minus 60 mesh) is mixed with the melt in steam-heated tanks, usually in a ratio of 60% nitrate to 40% limestone. The prilling tower is basically a spray chamber through which the melt falls against a counter current of hot air.

It is said that the shorter prilling tower affords a 50% saving in construction costs, that the ammonium nitrate prills have a higher density than those processed in orthodox towers, resulting in better qualities, and that the product contains less than 1% fines. An additional advantage is that the separate drying stage normally required is unnecessary since the ammonium nitrate is practically anhydrous before entering the prilling stage. It is reported that this prilling system can be used for most fertilizer materials including urea.

Non-Caking Ammonium Nitrate

The Monsanto Chemical Company has announced the development of a high density, dust-free, non-caking prilled ammonium nitrate to be marketed under the trade name of Lion E-2. It is reported that this material does not cake at a pressure of 600lbs. per sq. inch and that on account of its high density it requires 20% less storage space that other grades of prilled ammonium nitrate. These properties are achieved in the processing and not by the addition of a coating, but details of the process are not at present released.

Lion E-2 is being manufactured at the El Dorado, Ark., and Luling, La., plants operated by the Lion Oil Co., a division of Monsanto Chemical Co. Built by the Chemical Construction Corporation of New York, these plants have a combined capacity exceeding 400,000 tons of ammonium nitrate a year. The International Ore & Fertilizer Corp. of New York are the sole marketing agents of ammonium nitrate for Monsanto in the United States.

Mississippi Chemical Corporation's New Urea Plant

The Mississippi Chemical Corporation plans to build a $1½ million urea plant at Yazoo City, Miss., to produce 100 tons of prilled or crystallized urea a day. In addition, Mississippi Chemical will spend $650,000 on extensions to the ammonia facilities of its subsidiary, the Coastal Chemical Corporation at Pascagoula, Miss., which built by the Chemical Construction Corporation, are to be extended in the near future.

A farmers' co-operative, the Mississippi Chemical Corporation, uses natural gas to produce ammonia in a Claude high pressure synthesis plant with a daily capacity of 320 tons. The Corporation also operates four Du Pont type nitric acid units—three with capacities of 60 tons per day and one with a capacity of 180 tons a day—acid produced in these plants being used in the manufacture of 525 tons of ammonium nitrate daily.

Solar Nitrogen Chemicals to operate New Acrylonitrile Plant

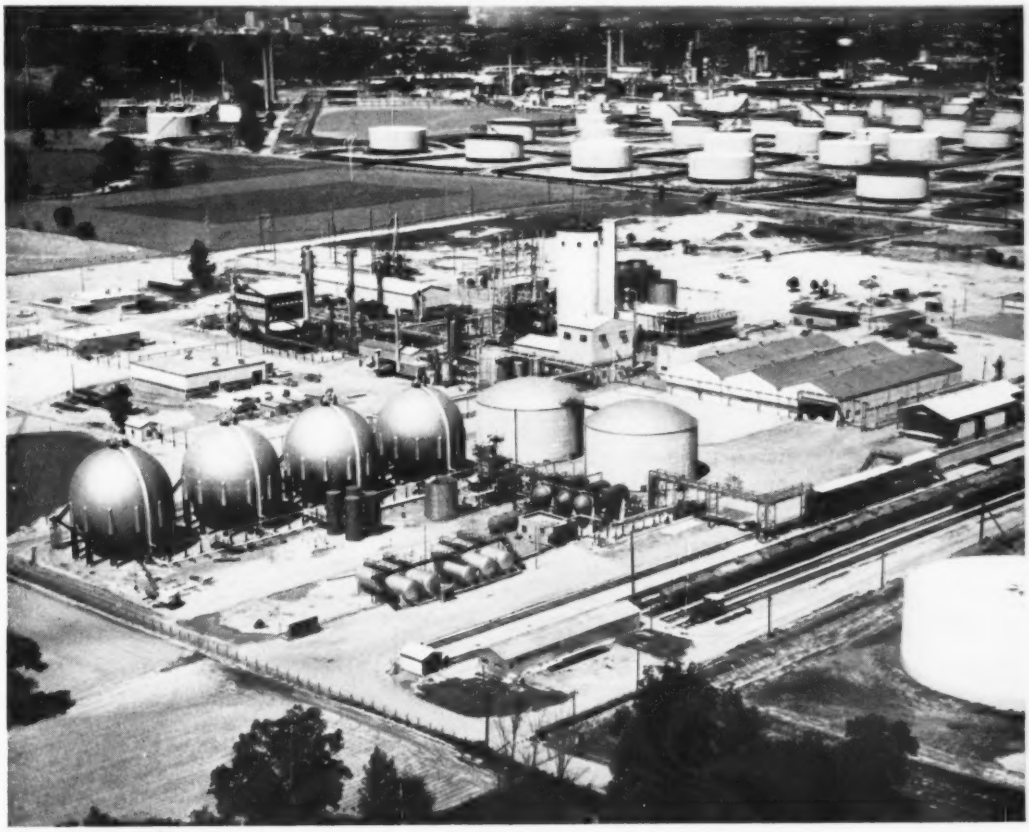
Formed by the Standard Oil Co. (Ohio) of Cleveland and the Atlas Powder Co. of Wilmington, Del., Solar Nitrogen Chemicals Inc. will acquire all the ammonia and related petrochemical facilities of the Sohio Chemical Co. at Lima, Ohio. The latter, a subsidiary of the Standard Oil Co., Ohio, will continue to operate the plant and act as sales agent for the new company.

The Lima plant, completed in the summer of 1957, has a daily capacity of 300 tons of ammonia based on the use of natural or refinery waste gas, 180 tons of 58-62% strength nitric acid (100% HNO_3) employing an adaption of the Du Pont process and 120 tons of urea by the Inventa process. The principal fertilizer materials manufactured are ammonium nitrate and urea solutions. The Atlas Powder Co., an important explosives manufacturer

consuming large quantities of ammonia in the production of nitric acid and ammonium nitrate at Atlas, Mo., and Reynolds, Pa., bought the interest in the Lima plant through Solar Nitrogen Chemicals to ensure its ammonia supplies.

Now Solar Nitrogen Chemicals will also acquire the acrylonitrile plant to be installed at Lima which is due to come into operation early in 1960. The capacity of this plant has not yet been made known but a new process, developed by the Sohio Chemicals Co., will be employed and acetonitrile will be recovered as a by-product.

Acrylonitrile is consumed in the manufacture of wool-like fibres for sweaters, suiting, carpeting and synthetic furs and is a component in many types of plastic, and is used in chemical and oil resistant nitrile rubbers. The current manufacturing capacity in the United States exceeds 152,000 short tons a year which is about 1.7 times greater than in 1958, the anticipated growth of demand having been over-estimated.



Sohio Chemicals Co. General view of the ammonia and urea installations at Lima, Ohio.

As with acrylonitrile, there is a substantial measure of over-capacity in acetonitrile. Although the quantity of acetonitrile recovered at the Lima plant will be small compared with the tonnage of acrylonitrile produced, it will be obtained in commercial quantities. Doubts have been expressed as to the sales potential of this product, but while admitting that it is

limited at present, Sohio expects to develop new markets and have indicated that appreciably greater quantities could be sold at prices lower than the present price of 45 cents a pound. Highly promising applications are in the separation of olefins, as an extractive distillation solvent, as a reagent and processing medium and as a raw material in the manufacture of certain chemicals.

YUGOSLAVIA

Italians to build Lukavac Nitrogen Plant

Two Italian firms, Soc. Montecatini of Milan and Soc. Ansaldo of Genoa, have signed an $8.5 million contract with " Rudnap," the Yugoslavian State-controlled chemical organisation, for the erection of a nitrogen fertilizer plant at Lukavac in Bosnia. Construction is to start immediately and the new plant is expected to be in operation by 1961. Gas will be supplied from coke ovens already in operation at the Lukavac works where by-product ammonium sulphate is already being obtained at an annual rate of 9,000 tons. The Fauser-Montecatini processes will be employed in the new plant which will have a capacity of 100 metric tons of anhydrous ammonia, 340 metric tons of nitric acid and 380 metric tons of lime ammonium nitrate per day. Most of the equipment and machinery will be supplied by Ansaldo.

Another important nitrogen fertilizer plant is already under construction at Pancevo by the Chemical Construction Corporation and will have an annual capacity of 370,000 tons of lime ammonium nitrate based on the use of natural gas from the Vojvodina area. This plant was originally to have been built with financial and technical assistance from the Soviet Union, but since the cancellation of U.S.S.R. credits, Yugoslavia has turned to the United States for assistance with the $45 million project. The United States Development Loan Fund is to advance $22.5 million, the foreign exchange requirement for this plant.

A smaller nitrogen fertilizer plant is being built at Jegunovci and is to have a capacity of 33,000 tons of calcium cyanamide a year. Calcium cyanamide is already manufactured at Dugirat where the plant originally operated by the Société Dalmatienne has been rebuilt and production is now at a level of 13,000 tons a year. Other plants at present in operation in Yugoslavia are those at Gorzda, producing ammonium nitrate, and at Zenica where ammonium sulphate is manufactured as a by-product from coke-ovens.

Nitrogen production in Yugoslavia has risen from 4,700 tons N in 1954 to its present level of over 6,000 tons N a year, while the new plants planned or already under construction can be expected to raise production to over 100,000 tons of nitrogen within the next five years. Consumption of nitrogen fertilizers in Yugoslavia amounted to over 20,000 tons N in 1954 and has since risen to 95,000 tons a year, mainly in the form of ammonium nitrates. Imports which have increased with the rising consumption can be expected to fall off sharply before 1965 unless fertilizer usage, already high, receives an unexpected stimulus.

Statistical Appendix

United States

PRODUCTION

Short Tons

		Anhydrous Ammonia	Ammonium Nitrate (100% NH_4NO_3)		Ammonium Sulphate		Nitric Acid	Nitrogen Solutions
		Synthetic	Total	Fertilizer	Synthetic	By-product	(100% HNO_3)	(100% N)*
1957	**TOTAL**	**3,734,213**	**2,586,007**	**2,338,576**	**1,039,822**	**908,903**	**2,843,488**	**563,423**
1958	**TOTAL**	**3,831,420**	**2,524,057**	**2,272,905**	**1,097,750**	**640,852**	**2,601,915**	**631,903**
	January	326,896	239,036	213,544	83,451	57,759	252,085	40,516
	February	286,734	203,468	181,686	80,777	48,375	213,289	50,746
	March	339,015	240,785	217,501	101,116	53,001	245,543	64,364
	April	329,837	231,228	208,512	97,603	48,793	235,477	82,337
	May	348,158	186,417	167,122	104,410	49,148	210,050	62,092
	June	336,309	154,204	139,007	97,917	49,328	175,535	35,429
	July	294,664	176,748	162,311	85,776	48,019	191,792	30,283
	August	280,581	184,742	166,244	84,231	50,114	196,916	40,161
	September	304,753	208,760	186,150	92,583	51,526	223,748	56,088
	October	325,987	233,259	208,362	84,475	58,455	254,529	49,256
	November	333,860	237,067	214,407	96,327	61,564	258,135	54,078
	December	324,626	228,343	208,059	89,084	64,770	244,816	66,553
1959	January	333,805	227,887	207,464	88,531	63,604	240,780	52,119
	February	326,454	216,428	193,386	87,075	63,817	240,969	56,768

* Including combinations with urea.

Italy

Tonnes

PRODUCTION

		Ammonium Sulphate (20-21% N)	Ammonium Nitrate (20-26.5% N)	Ammonium Nitrate (33-35% N)	Calcium Nitrate (13-15.5% N)	Calcium Cyanamide (15-16% N)	Urea (44-45% N)
1957	**TOTAL**	**800,064**	**381,572**	**115,877**	**280,609**	**142,173**	**89,744**
1958	**TOTAL**	**897,682**	**488,766**		**327,632**	**187,604**	**67,613**
1957	1st quarter	176,873	90,183		72,750	18,685	
	2nd quarter	195,686	79,369		68,250	32,569	
	3rd quarter	214,054	114,138		68,034	49,848	
	4th quarter	213,451	97,882		71,575	41,071	
1958	1st quarter	169,592	127,273		90,050	24,729	18,114
	2nd quarter	199,063	110,322		66,713	68,582	16,603
	3rd quarter	271,772	134,837		72,807	53,586	15,166
	4th quarter	257,255	116,334		98,062	40,707	17,729

EXPORTS

		Ammonium Nitrate				Urea			
		Total	U.S.A.	Yugoslavia	China		Total	India	China
1957	**TOTAL**	**164,959**	**15,240**	**88,921**	**26,555**	**1957 TOTAL**	**57,154**	**34,477**	**15,625**
1958	**TOTAL**	**360,596**	**13,152**	**71,290**	**49,559**	**1958 TOTAL**	**51,727**	**20,018**	**22,600**
1957	1st quarter	61,005	7,257	44,530	—	1957 1st quarter	6,827	4,057	—
	2nd quarter	23,930	—	14,381	8,991	2nd quarter	23,547	12,987	8,719
	3rd quarter	56,312	3,992	29,078	7,420	3rd quarter	14,147	13,369	—
	4th quarter	23,712	3,991	932	8,144	4th quarter	12,633	4,064	6,906
1958	1st quarter	33,292	9,977	11,569	—	1958 1st quarter	6,953	—	3,316
	2nd quarter	59,979	—	34,929	9,018	2nd quarter	18,276	9,923	5,001
	3rd quarter	86,258	3,175	8,338	—	3rd quarter	14,533	6,795	6,000
	4th quarter	181,067	—	26,453	40,541	4th quarter	11,965	3,300	8,283

		Ammonium Sulphate				
		Total	Pakistan	China	South Korea	Greece
1957	**TOTAL**	**239,033**	**—**	**112,036**	**—**	**59,258**
1958	**TOTAL**	**319,980**	**43,676**	**67,304**	**69,203**	**72,354**
1957	1st quarter	35,580	—	—	—	12,155
	2nd quarter	72,466	—	37,345	—	8,738
	3rd quarter	72,819	—	38,565	—	33,400
	4th quarter	58,368	—	36,126	—	4,965
1958	1st quarter	76,875	—	10,490	36,311	11,470
	2nd quarter	89,359	34,098	10,000	25,492	21,614
	3rd quarter	95,736	9,578	39,114	7,400	30,388
	4th quarter	58,010	—	7,700	—	8,882

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